EXHIBIT A

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Johnston

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(54) **LIGHT-GENERATING SYSTEM**

(76) Inventor: **John F. Johnston**, Paris (CA)

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(22) Filed: **Jun. 10, 2010**

Related U.S. Application Data

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(51) **Int. Cl.**

G05F 1/00	(2006.01)
H01L 27/14	(2006.01)

(52) **U.S. Cl.** ..... **315/309**; 315/291; 315/247; 315/185 S; 315/312; 362/800; 362/373; 362/546; 362/547

(58) **Field of Classification Search** .... 362/580, 362/547, 218, 294, 345, 373, 800–812; 315/149–159, 307–326, 185 S, 291, 224, 315/247

See application file for complete search history.

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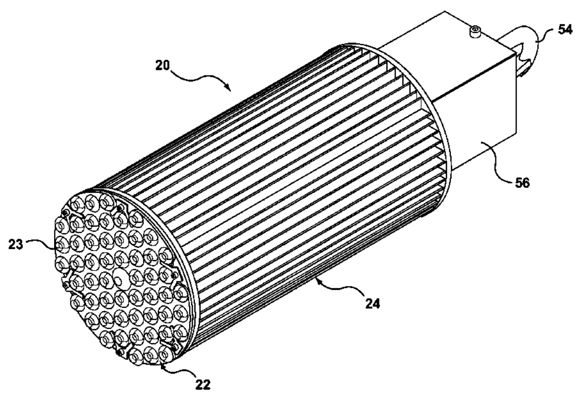
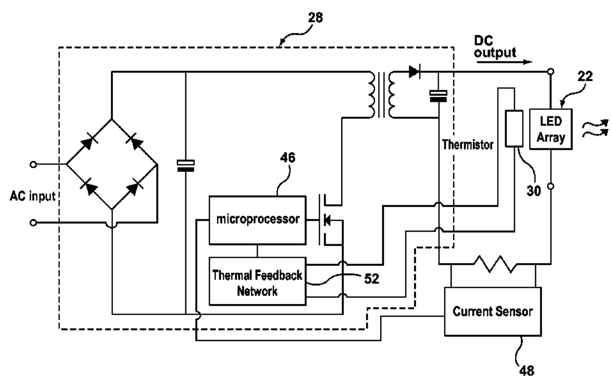
Primary Examiner — Tuyet Thi Vo

(57) **ABSTRACT**

A light-generating system including a LED load array having a number of light-emitting diodes, and a heat sink on which the LED load array is mounted. The system also includes a power control unit electrically connected to the power source and the LED load array, for converting input electrical power to output electrical power and controlling voltage and current of the output electrical power provided to the LED load array, and a temperature detector subassembly adapted for sensing a heat sink temperature of the heat sink. The temperature detector subassembly monitors the heat sink temperature and transmits a control signal to the power control unit upon determining that the heat sink temperature differs from a preselected temperature by more than a preselected minimum difference. Upon receipt of the control signal, the power control unit changes the voltage of the output electrical power accordingly.

8 Claims, 11 Drawing Sheets





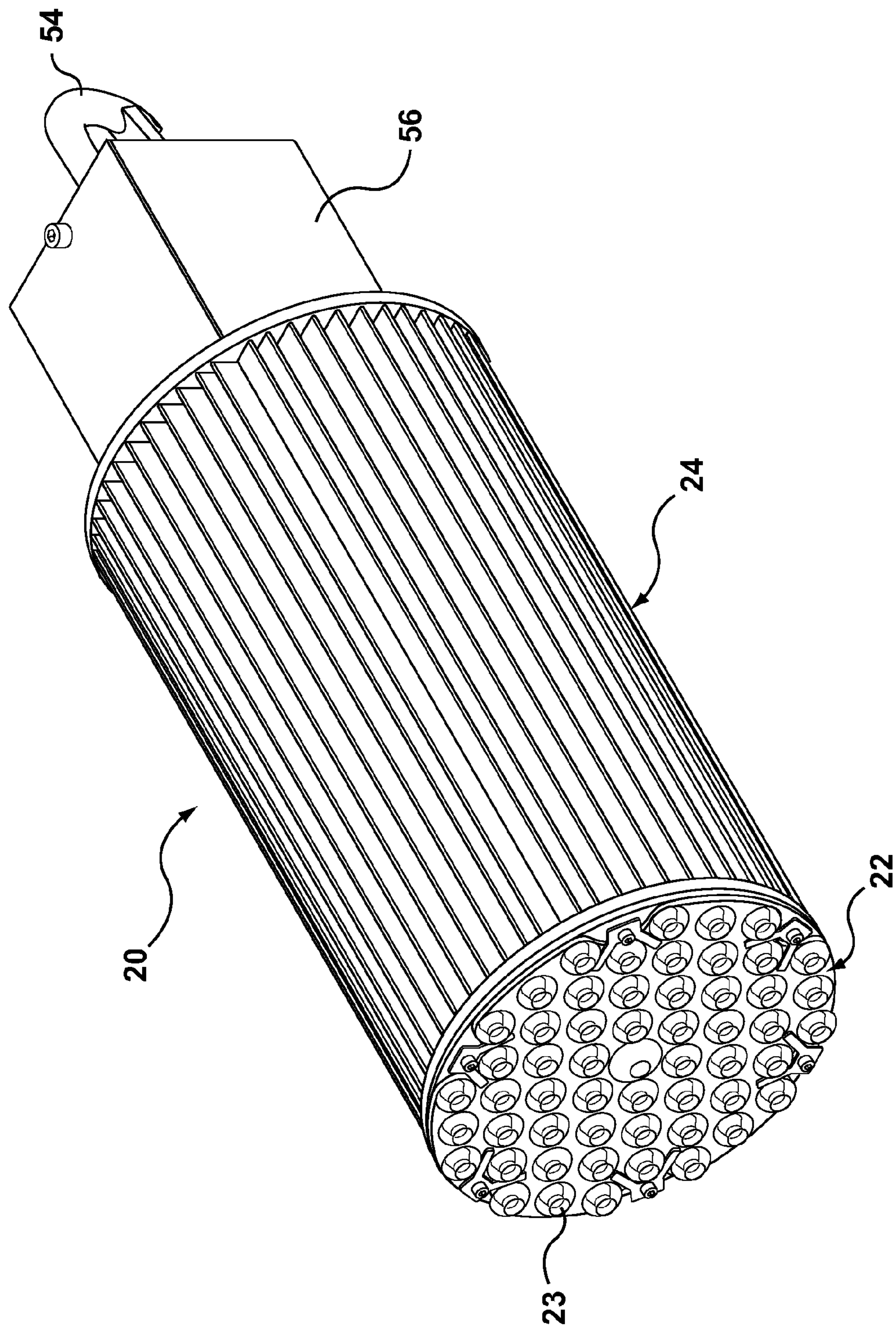


FIG. 1A

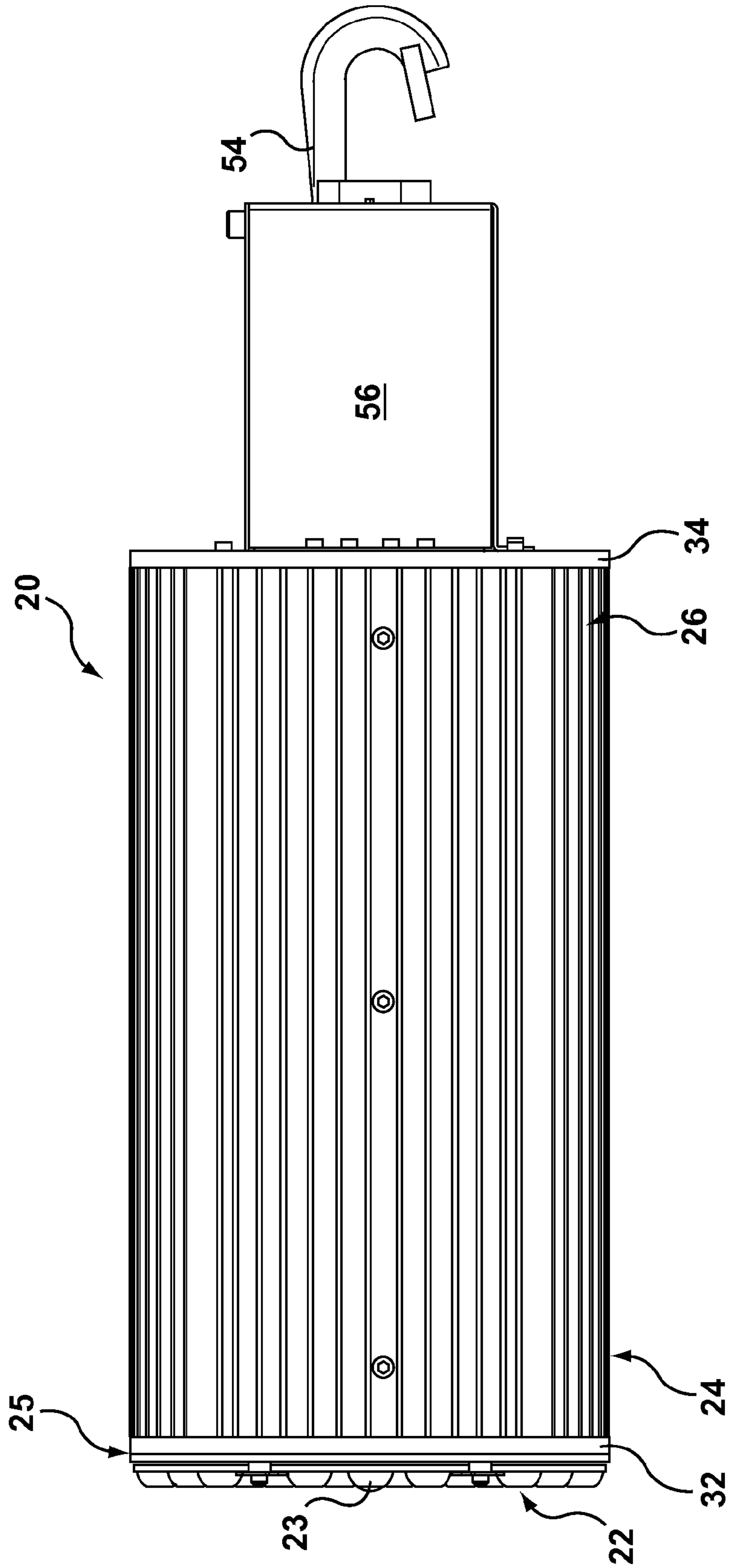


FIG. 1B

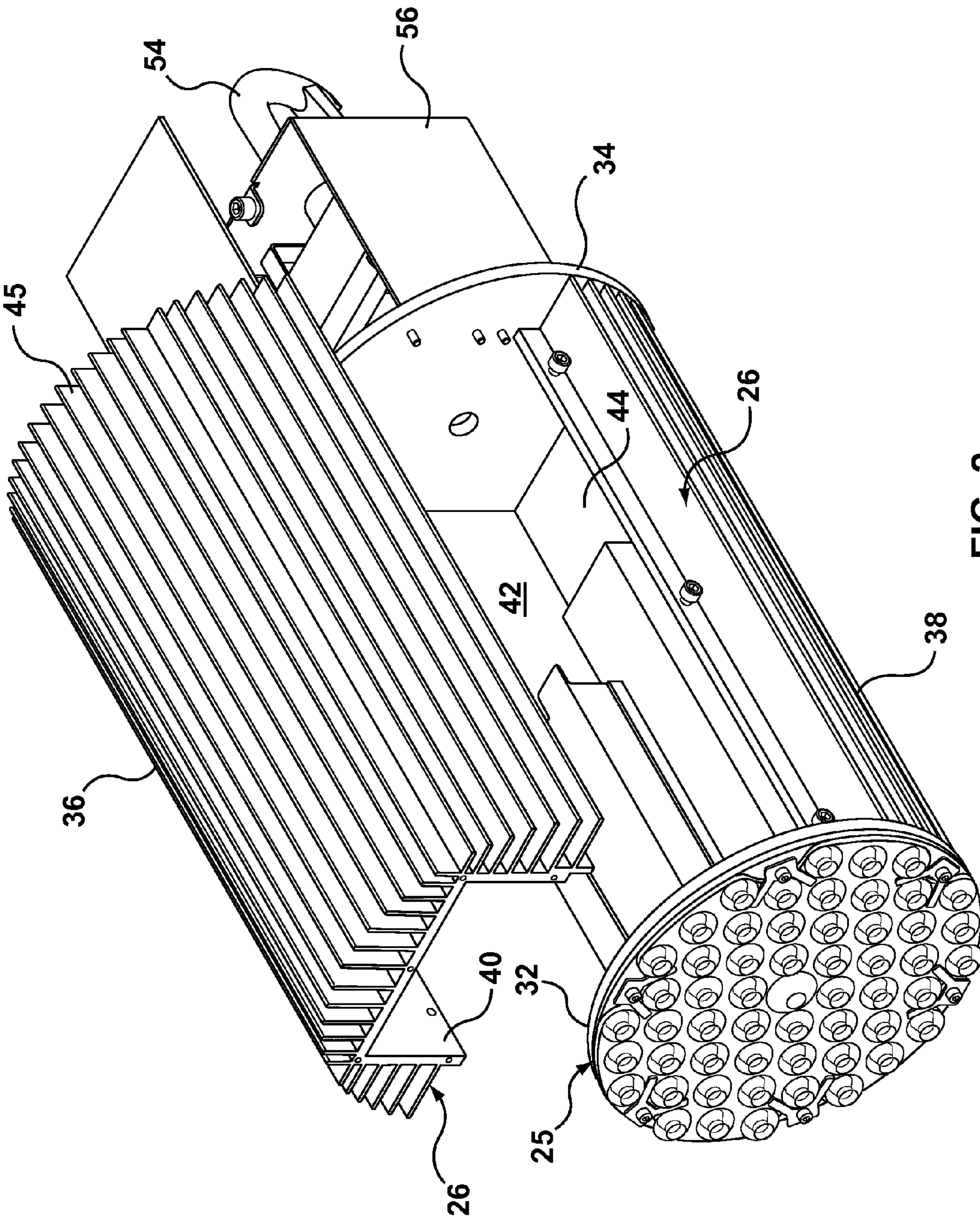


FIG. 2

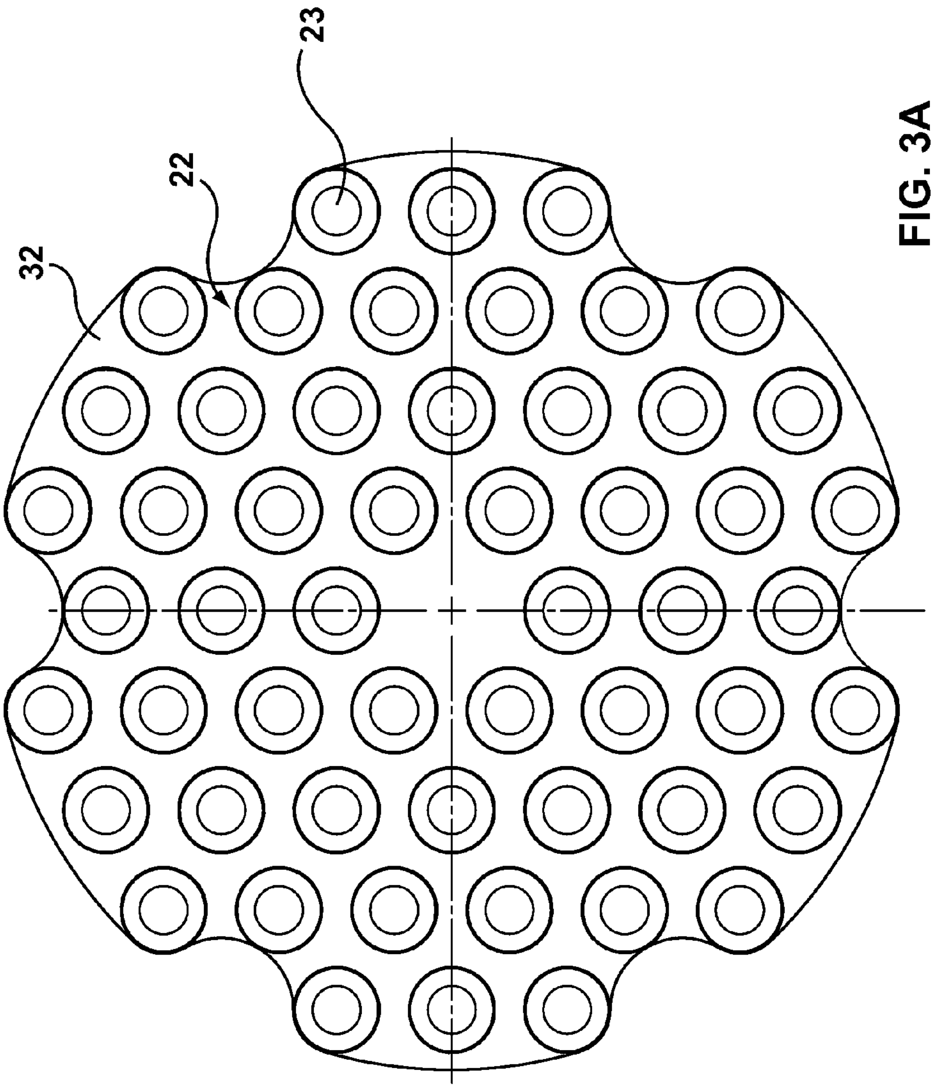


FIG. 3A

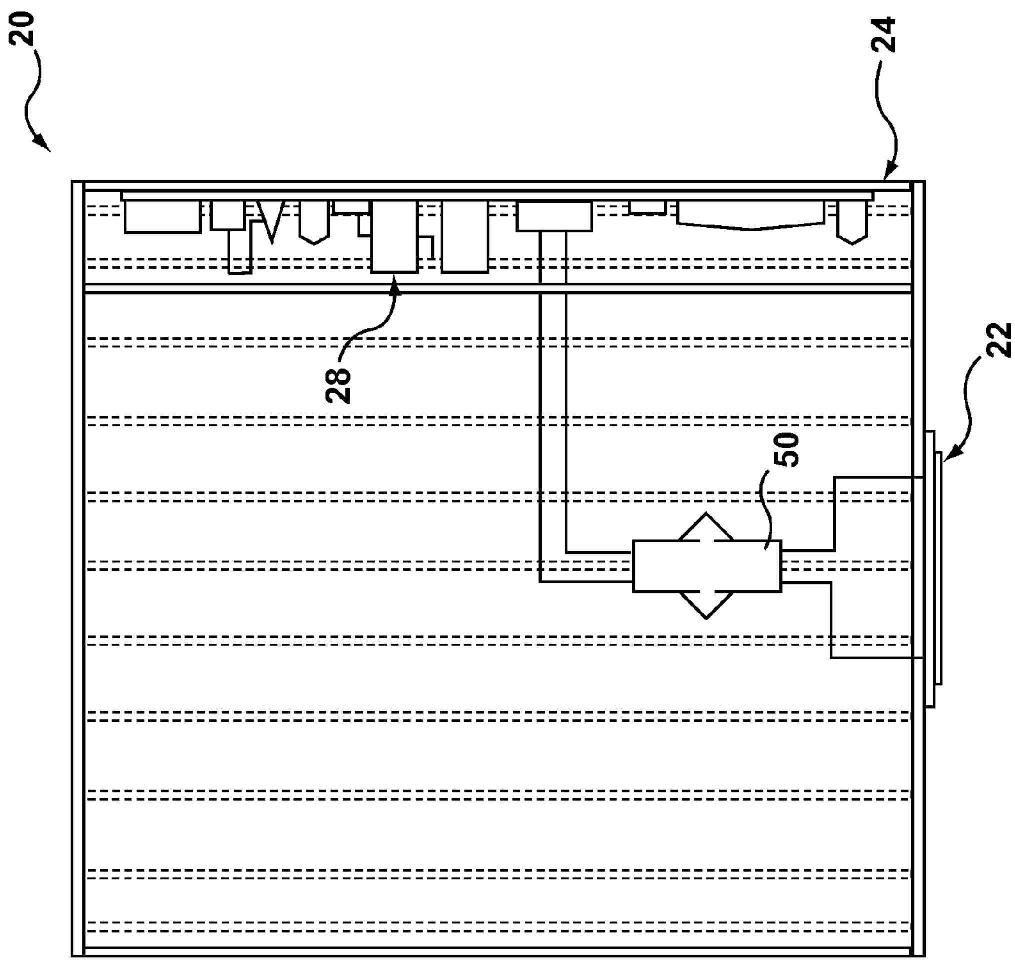


FIG. 3B

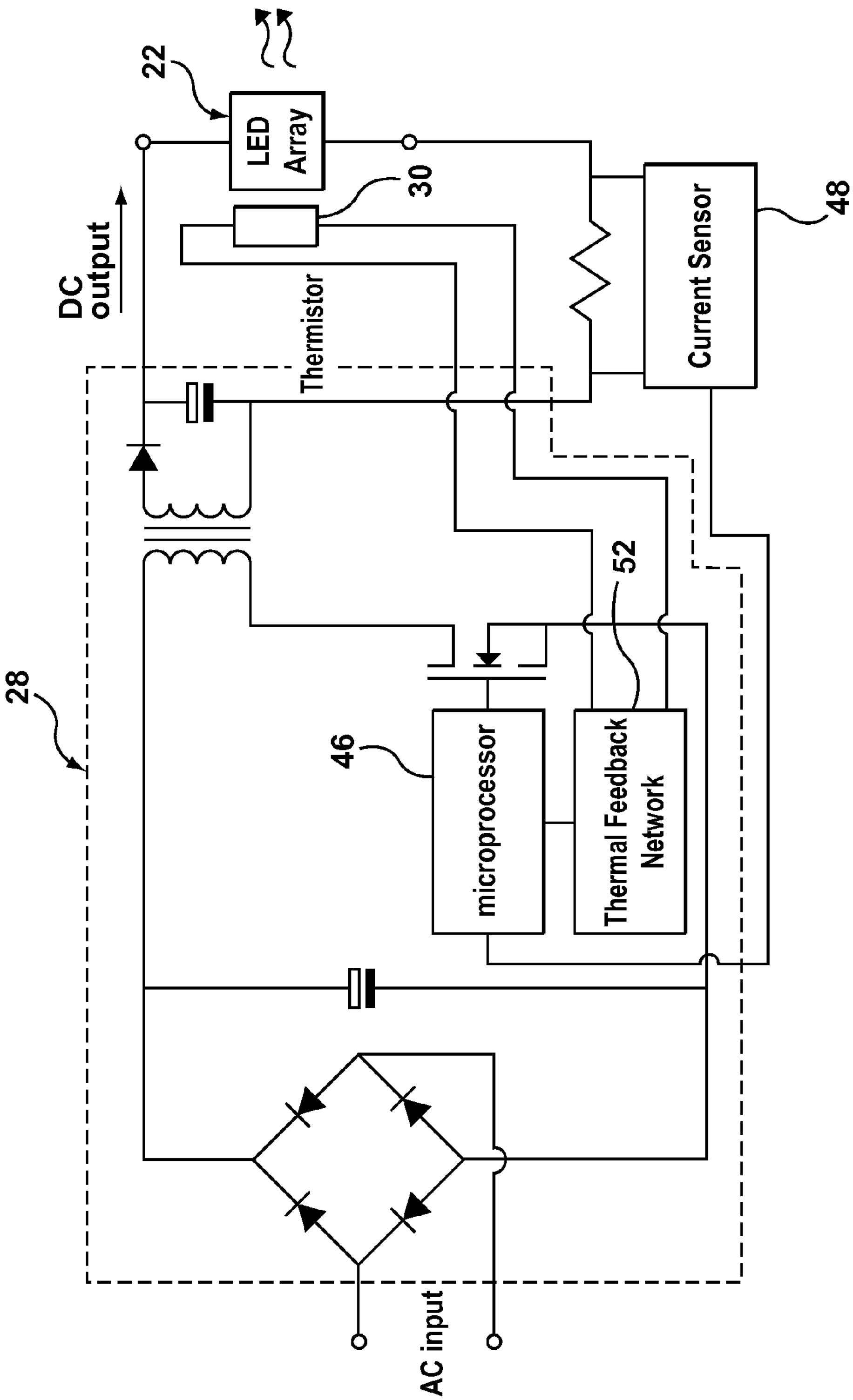
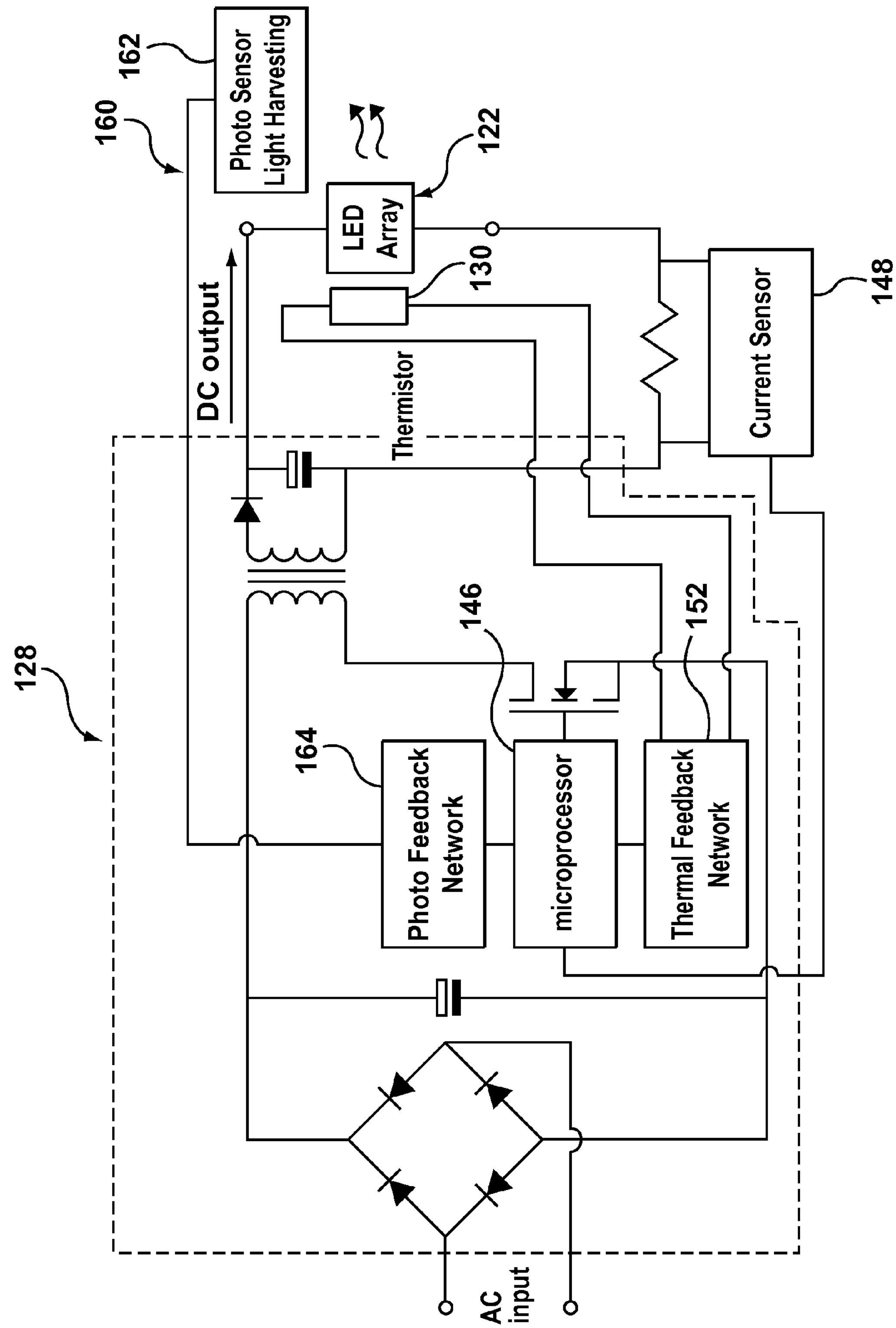

22
LED Array
30
DC output
Thermistor
Current Sensor
48
28
52
46
microprocessor
Thermal Feedback Network
AC input

FIG. 4A



162
Photo Sensor
Light Harvesting
160
122
LED
Array
130
148
Current Sensor
DC output
Thermistor
128
146
152
164
Photo Feedback
Network
microprocessor
Thermal Feedback
Network
AC
input

FIG. 4B

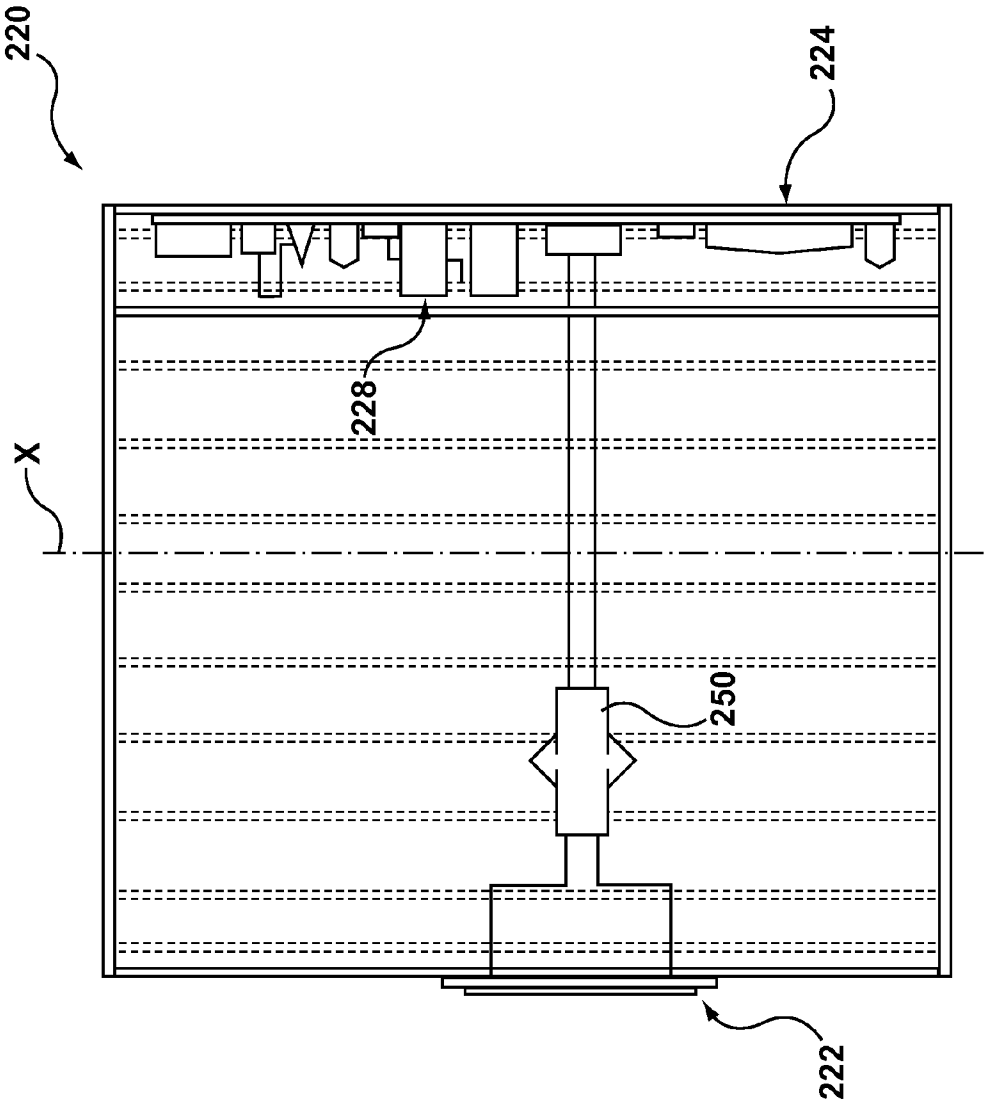


FIG. 5

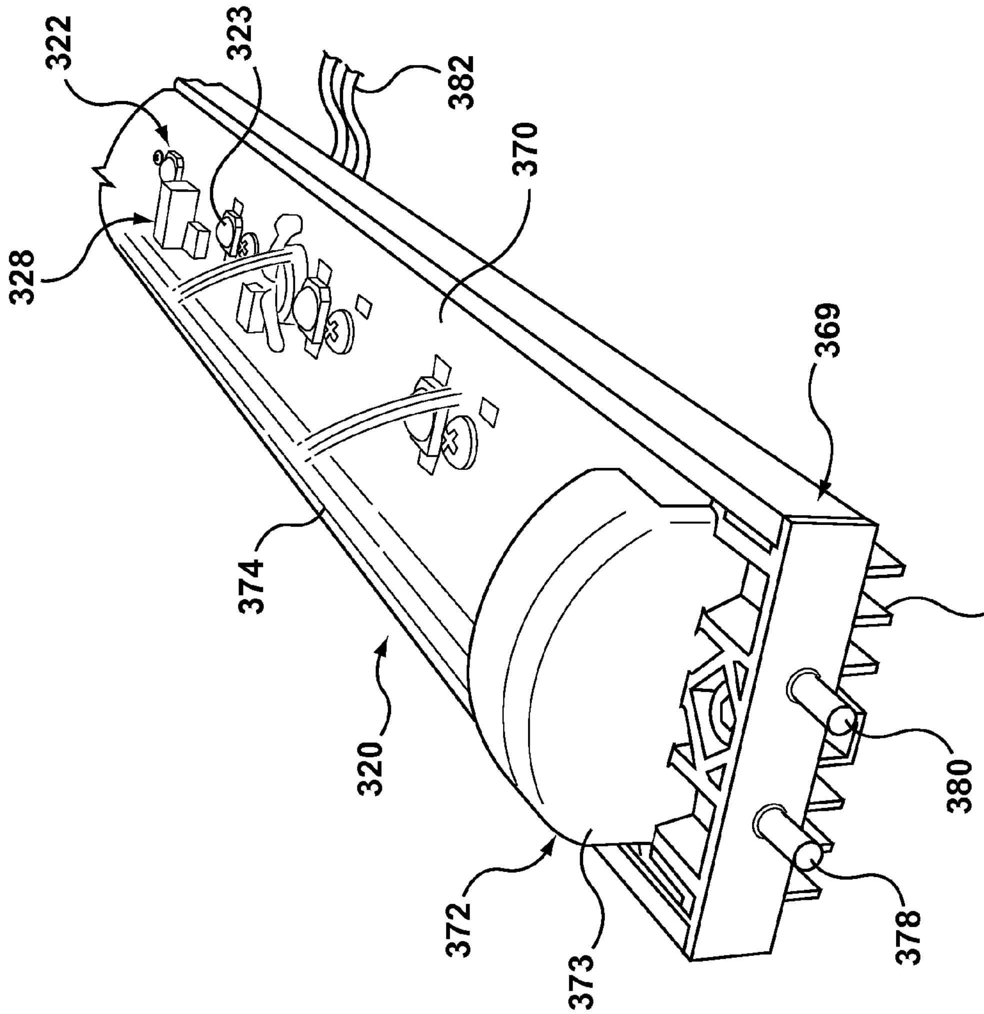


FIG. 6

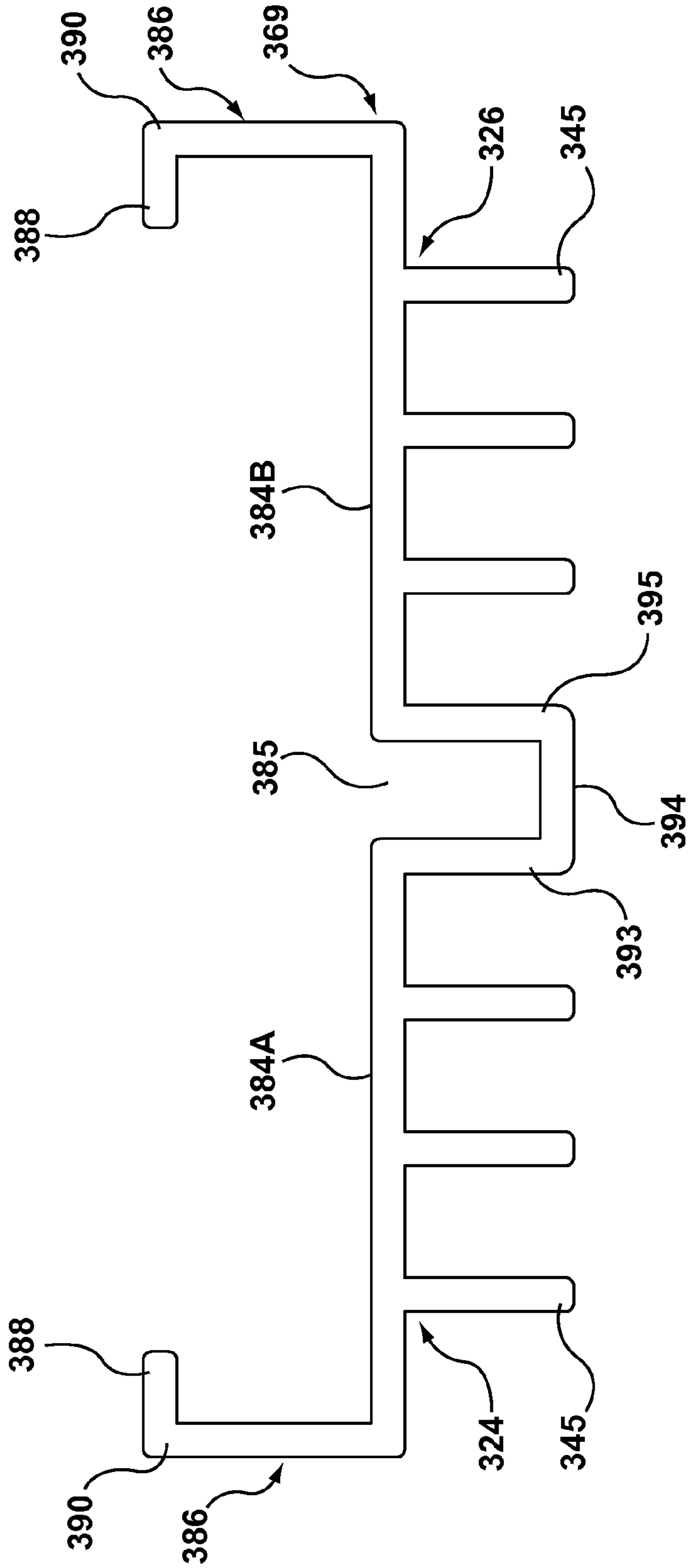

390
386
369
326
345
388
384B
395
385
394
393
384A
388
345
324
390
386

FIG. 7

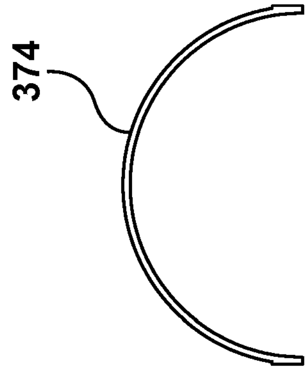


FIG. 8B

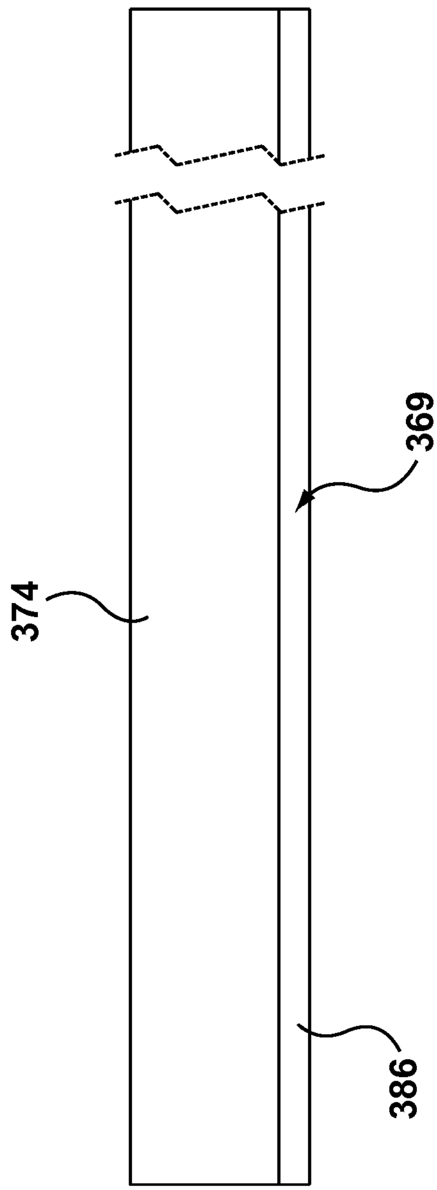


FIG. 8A

LIGHT-GENERATING SYSTEM

This application claims the benefit of U.S. Provisional Patent Application No. 61/185,731, filed Jun. 10, 2009, and incorporates such provisional application in its entirety by reference.

FIELD OF THE INVENTION

The present invention is a light-generating system.

BACKGROUND OF THE INVENTION

As is well known in the art, light-emitting diodes ("LEDs") are more efficient than incandescent light bulbs, i.e., more light is produced per watt by an LED than by an incandescent bulb. Other known electrically-powered light sources, e.g., fluorescent light bulbs, have a number of disadvantages, as is well known in the art. For example, fluorescent light bulbs are required to be replaced relatively frequently. Where they are used in streetlights, this can involve significant expenses.

LEDs have a number of additional advantages. However, as is well known in the art, LEDs require relatively close control of voltage and current and also heat management. For example, because current through the LED is dependent exponentially on voltage, voltage should be closely controlled. Also, the voltage supplied should be sufficient, at a minimum, to cause current to flow in the proper direction (i.e., from p-type to n-type material). In addition, the ambient temperature of the operating environment can significantly affect the performance of LEDs.

Although LEDs have certain advantages when compared to incandescent or fluorescent bulbs (e.g., lower power consumption, and longer operating time) LEDs also have certain disadvantages, as noted above.

SUMMARY OF THE INVENTION

For the foregoing reasons, there is a need for an improved light-generating system, in which one or more of the disadvantages of the prior art are addressed or mitigated.

In its broad aspect, the invention provides a light-generating system for consuming input electrical power from a power source to generate light. The light-generating system includes a LED load array with a plurality of light-emitting diodes, the light-emitting diodes having an operating temperature when energized, and a heat sink on which the LED load array is mounted, the heat sink being adapted for absorbing and dissipating heat energy generated by the light-emitting diodes when energized. The heat sink includes a body portion to which the light-emitting diodes are attached, and a finned portion connected to the body portion, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes, to cool the light-emitting diodes. The system also includes a power control unit electrically connected to the power source and the LED load array, for converting the input electrical power to an output electrical power and controlling voltage and current of the output electrical power provided by the power control unit to the LED load array. In addition, the system includes a temperature detector subassembly operatively connected to the power control unit, the temperature detector subassembly being adapted for sensing a heat sink temperature of the heat sink at one or more predetermined locations thereon.

The temperature detector subassembly is adapted to compare the heat sink temperature to one or more preselected temperatures within a preselected temperature range, and to transmit a control signal to the power control unit upon determining that the heat sink temperature differs from said at least one preselected temperature by more than a preselected minimum difference.

Upon receipt of the control signal, the power control unit changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes such that the heat sink temperature is within the preselected temperature range.

In one of its aspects, the preselected temperature includes an upper limit preselected temperature, and the preselected minimum difference includes an upper limit minimum difference.

In another aspect, upon the temperature detector subassembly determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range.

In yet another aspect, the control signal causes the voltage of the output electrical power to decrease to an extent required by the control signal.

In yet another of its aspects, the power control unit of the invention includes a microprocessor and a current sensor, for determining current data associated with the output electrical power and communicating the current data to the microprocessor.

In another aspect, the invention additionally includes an ambient light controller for controlling the electrical power provided to the LED load array, in indirect proportion to ambient light intensity.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood with reference to the attached drawings, in which:

FIG. **1**A is an isometric view of an embodiment of a light-generating system of the invention;

FIG. **1**B is a side view of the light-generating system of FIG. **1**A;

FIG. **2** is an exploded view of the light-generating system of FIG. **1**A;

FIG. **3**A is a plan view of a bottom plate subassembly of the light-generating system of FIG. **1**A, drawn at a larger scale;

FIG. **3**B is a schematic illustration of the light-generating system of FIG. **1**A;

FIG. **4**A is a schematic diagram illustrating the light-generating system of FIGS. **1**A-**3**;

FIG. **4**B is a schematic diagram illustrating an alternative embodiment of the light-generating system of the invention;

FIG. **5** is a schematic illustration of another alternative embodiment of the light-generating system of the invention;

FIG. **6** is an isometric view of an alternative embodiment of the light-generating system of the invention, drawn at a smaller scale;

FIG. **7** is an end view of a base of the light-generating system of FIG. **6**, drawn at a larger scale;

FIG. **8**A is a side view of selected elements of the light-generating system of FIG. **6**, drawn at a smaller scale; and

FIG. **8**B is an end view of a cover of the light-generating system of FIG. **6**, drawn at a larger scale.

DETAILED DESCRIPTION

In this specification and in the claims that follow, "LED" means a light-emitting diode. In the attached drawings, like

reference numerals designate corresponding elements throughout. Reference is first made to FIGS. **1**A-**4**A to describe an embodiment of a light-generating system of the invention indicated generally by the numeral **20**. The light-generating system **20** is for consuming input electrical power from a power source (not shown) to generate light. Preferably, the light-generating system **20** includes a LED load array **22** with a number of light-emitting diodes **23**, which have an operating temperature when energized. The system **20** also preferably includes a heat sink **24** on which the LED load array **22** is mounted. The heat sink **24** is adapted for absorbing and dissipating heat energy generated by the light-emitting diodes **23**, when they are energized. It is preferred that the heat sink **24** includes a body portion **25** to which the light-emitting diodes **23** are attached, and a finned portion **26** connected to the body portion **25**, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes **23**, to cool the light-emitting diodes **23**. In addition, the system **20** preferably includes a power control unit **28** electrically connected to the power source and the LED load array **22**, for converting the input electrical power to an output electrical power, and for controlling voltage and current of the output electrical power provided by the power control unit **28** to the LED load array **22**. In one embodiment, the system **20** preferably also includes a temperature detector subassembly **30** operatively connected to the power control unit **28**. The temperature detector subassembly **30** is adapted for sensing a heat sink temperature of the heat sink **24** at a predetermined location thereon. As will be described, the temperature detector subassembly **30** preferably is also adapted to compare the heat sink temperature to one or more preselected temperatures within a preselected temperature range, and to transmit a control signal to the power control unit **28** upon determining that the heat sink temperature differs from the preselected temperature by one or more preselected minimum differences. Upon receipt of the control signal, the power control unit **28** changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes so that the heat sink temperature is within the preselected temperature range.

As can be seen in FIGS. **1**A-**3**A, in one embodiment, the body portion **25** of the heat sink **24** preferably includes first and second end plates **32**, **34** to which the finned portion **26** is attachable (FIG. **2**). Preferably, the end plates **32**, **34** are substantially round in plan view thereof, with substantially the same diameter. As shown in FIG. **2**, it is preferred that the finned portion **26** includes first and second parts **36**, **38** which, when attached to the end plates **32**, **34**, define a generally cylindrical shape overall. Each of the first and second parts **36**, **38** includes an interior surface **40**, **42** (FIG. **2**). It will be understood that, when the heat sink **24** is assembled, the interior surfaces **40**, **42** and the end plates **32**, **34** at least partially define a cavity **44** in which certain elements (e.g., the power control unit **28**) are positionable. For instance, as schematically illustrated in FIG. **3**B, the power control unit **28** preferably is mounted on one or more of the interior surfaces **40**, **42**.

The heat sink **24** preferably includes any suitable heat dissipation means. For example, depending on the application, one or more heat pipes may be suitable. However, it is preferred that the heat sink **24** includes fins **45** which extend outwardly from the finned portion **26** for heat exchange with the ambient atmosphere, to dissipate heat to the ambient atmosphere. Preferably, the fins **32** are formed for optimal heat transfer characteristics. It will be appreciated by those skilled in the art that the heat sink preferably is made of material with relatively high thermal conductivity. For example, the heat sink **24** preferably is made of extruded aluminum.

It is preferred that the power control unit **28** includes a microprocessor **46** and a current sensor **48**, for determining current data associated with the output electrical power and communicating the current data to the microprocessor **46** (FIG. **4**A).

The power control unit **28** preferably provides a current-regulated and voltage-regulated power supply to the LED load array **22**. Preferably, the components of the power control unit **28** are included in a highly integrated single power/controller board design (i.e., a printed circuit board ("PCB")), which is a microprocessor-based control system that fits within the heat sink **24**. In one embodiment, the power control unit **28** and other elements of the light-generating system **20** preferably are adapted for 50 W or 100 W rated output, as selected by the user. Preferably, the power control unit **28** is set for either 50 W or 100 W when it is manufactured. This arrangement reduces manufacturing costs. Other possible power outputs will occur to those skilled in the art.

It is also preferred that the system **20** includes a connector **50**, for electrically connecting the LED load array **22** to the power control unit **28**. The connector **50** preferably is adapted for quick connection and disconnection, to permit relatively quick replacement of a used LED load array **22**.

The light-generating system **20** preferably includes continuous diagnostics for supply, lamp load condition and system functionality. The power measurement and control capability of the power control unit **28** leads to a relatively longer operational life of the LED load array **22**.

Preferably, the microprocessor **46** is for monitoring and controlling various aspects of the performance of the power control unit **28** and/or the light-generating system **20** overall. In particular, the microprocessor **46** receives data about the current and voltage provided to the LED load array **22**, compares such measured current and voltage to rated current and voltage, and initiates appropriate action if the measured current and voltage vary from the rated values therefor by more than predetermined differences respectively. Preferably, the output electrical power is controlled via pulse width modulation. It is preferred that voltage is monitored within the microprocessor **46**. Current preferably is sensed by the sensor **48**, and data in this regard is provided to the microprocessor **46**. The microprocessor **46** then directs the pulse lengths accordingly. The microprocessor **46** continuously processes such data at very short time intervals.

The LED driver **28** sets the voltage applied to the LED load array **22** in a variable fashion, where the microprocessor **46** adjusts the voltage slightly up or down within a given range in order to sense the predetermined current flow. The current flow is measured by a very low resistance power resistor (usually 0.1 Ohms) sensing a very small voltage drop across it (in milli-volts). This measurement is then amplified and put on a feedback to the microprocessor **46** so that it can adjust the potential of the pulses it feeds the output to attempt to match the pre-determined voltage drop across the current sensing resistor.

From the foregoing, it can be seen that the power control unit **28** is used to control the voltage applied to the LED load array **22**. However, unlike traditional supplies, an absolute output voltage is not set, but instead the applied voltage is set relative to the drop across a current-sensing resistor, as described above.

In addition, the light-generating system **20** has an overall power efficiency of at least 86 percent, a relatively high efficiency. (Prior art units typically average from 70 percent to 75

percent power efficiency.) The light-generating system **20** preferably has the full operational input range of 85-480 VAC.

In one embodiment, the light-generating system **20** preferably is adapted to automatically shut itself down immediately upon sufficiently unusual conditions being detected. For example, as the system **20** includes elements thereof adapted for measurement of current and voltage, if the current or voltage supplied is not within predetermined ranges, then the system **20** shuts down upon detection of the unusual conditions. If the applied voltage does not remain within its regulation parameters, then the system is shut down. Similarly, if the current supplied by the pulsing is insufficient to power the load, then the system **20** shuts itself down. Insufficient current may indicate that the system has a short circuit condition.

In addition, the light-generating system **20** preferably includes an automatic recovery function, pursuant to which the system **20** reboots itself if necessary. For instance, in the event of a complete failure of the power supply to the light-generating system **20**, the system **20** reboots itself once the power supply is restored.

In one embodiment, the light generating system **20** preferably includes the temperature detector subassembly **30** (FIG. **4**A) operatively connected to the power control unit **28** via a thermal feedback network **52** (FIG. **4**A). Those skilled in the art will be aware that the temperature detector subassembly may include various temperature-detecting elements. It is preferred that the temperature-detecting element in the temperature detector subassembly **30** is a thermistor. The temperature detector subassembly **30** is for sensing a temperature of the heat sink **24**. If the temperature differs from a preselected temperature by more than a predetermined extent, then the thermistor **30** provides an increasing signal to the power control unit **28**, for increasing the electrical power supplied to the LED load array **22**, or the thermistor **30** provides a decreasing signal to the power control unit **28**, for decreasing the electrical power supplied to the LED load array **22**, as the case may be. The thermistor **30** is adapted to take the ambient temperature into account. Because the thermistor **30** is included in the system **20**, a somewhat smaller heat sink **24** may be used than otherwise would be selected for the light-generating system.

It will be understood that, in practice, the location on the heat sink **24** at which the temperature thereof is detected preferably should be relatively proximal to the light-emitting diodes **23**. For instance, it is preferred that the thermistor **30** is connected to the heat sink **24** for detection of the temperature thereof at the end plate **32**. Those skilled in the art will appreciate that, in determining the temperatures which trigger the generation of control signals, the thermal conductivity of the heat sink **24** and the distance of the location at which temperature is detected is from the light-emitting diodes is taken into account.

In general, the power control unit **28** is required to lower the temperature of the heat sink. In one embodiment, the preselected temperature is an upper limit preselected temperature and/or a lower limit preselected temperature. Also, it is preferred that the preselected minimum difference is, when compared to the upper limited preselected temperature, an upper limit minimum difference, and when the operating temperature is compared to the lower limit preselected temperature, a lower limit minimum difference.

Preferably, upon the temperature detector subassembly **30** determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly **30** sends the control signal to the power control unit **28**, to cause the power control unit **28** to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range. The control signal preferably causes the voltage of the output electrical power to be decreased to an extent required by the control signal.

Preferably, upon the temperature detector subassembly **30** determining that the heat sink temperature is less than the lower limit preselected temperature by at least the lower limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit **28**, to cause the power control unit **28** to increase the output electrical power to raise the heat sink temperature until the heat sink temperature is within the preselected temperature range. The control signal preferably causes the voltage of the output electrical power to be increased to an extent required by the control signal.

It will be appreciated by those skilled in the art that the light-generating system **20** may be mounted in any suitable manner. Although many alternative arrangements are possible, in one embodiment, the system **20** preferably includes a hook element **54**, to enable the system **20** to be suspended by the hook element **54** attached to a suitable part of a building or other structure (not shown). Input electrical power preferably is provided via any suitable means, e.g., a suitable insulated power cord (not shown). As can be seen in FIGS. **1A-2**, the system **20** preferably includes a connection box **56** secured to the heat sink **24** in which the wiring (not shown) for connection with outside feed is located. In one embodiment, the hook element **54** is attached to the connection box **56**. It is preferred that the system not be mounted directly into a standard socket (e.g., a socket for accepting an E39 base) due to a requirement for a standards body's approval of both the socket and the light-generating system mounted in such socket.

In use, the system **20** is positioned as required, e.g., suspended by the hook element **54**, and the input electrical power is provided to the system **20** via any suitable means therefore. The light-emitting diodes preferably are fitted with one or more suitable lenses (not shown) for any particular application. For example, in view of the distance above a floor at which the light-emitting diodes are positioned, and the area to be illuminated, lenses with certain characteristics would be preferred. Once connected, the input electrical power is provided to the power control unit **28**. The power control unit **28** controls the voltage and current of the electrical power which is provided to the LED load array, so that it is within the appropriate parameters for safe operation of the LED load array. Among other things, if the input electrical power is AC, then AC current is rectified (to DC current) by the power control unit. Once the LED load array is operating, the heat sink dissipates heat, to provide a temperature within a predetermined operating range of the LED load array.

As described above, the thermistor preferably provides signals to the power control unit **28** to control the voltage of the output electrical power provided to LED load array **22**, in order to maintain the heat sink temperature within a predetermined range, in real time.

The light-generating system **20** is relatively robust, as all wiring and connectors are generally located inside the heat sink **24**, except for the power cord or other wiring for connection to an external power source. The heat sink **24** preferably also acts as a heat sink for the power control unit **28**. Preferably, the power control unit **28** is attached directly to an interior surface of the heat sink **24**, and positioned in the cavity **44** inside the heat sink **24**.

For reliability, it is preferred that the light-omitting diodes **23** are divided into a number of pairs of individual light-emitting diodes connected in series, and the pairs are con-

nected in parallel. For example, in one embodiment, the LED load array **22** preferably includes 54 light-emitting diodes **23** divided into 27 pairs, and the 27 pairs are connected in parallel. This arrangement is intended to result in greater reliability. If one light-emitting diode fails, then only the other light-emitting diode in that pair ceases to function as a result, because only such other light-emitting diode in that pair is connected in series to the failed light-emitting diode.

In one embodiment, the light-generating system **120** preferably additionally includes an ambient light controller **160** for controlling the electrical power supplied to the LED load array **122**, in indirect proportion to ambient light (FIG. **4**B). The ambient light controller **160** preferably includes an ambient light sensor **162** and a photo feedback network **164**. The sensor **162** notifies the feedback network **164** of changes in ambient light, and this data is provided to the microprocessor **146**. The microprocessor **146** is adapted to compare ambient light levels to predetermined light levels and to determine whether additional electrical power is required to be provided to the LED load array **122** (i.e., if ambient light is below a predetermined lower level) or, alternatively, whether the electrical power supplied to the LED load array **122** should be decreased (i.e., if ambient light is greater than a predetermined upper level). (It will be understood that "ambient light" to which a particular light-generating system **120** is exposed would also include, for instance, light produced by the LEDs in other light-generating systems positioned nearby.) Preferably, the power control unit **128** (FIG. **2**B) includes the pulse width modulator in the microprocessor **146** for "slowing down" (or, if necessary, "speeding up") the current provided to the LED load array **122**, thereby causing the LED load array **122** to provide less or more light, i.e., as required in indirect proportion to the ambient light.

In short, where the system of the invention includes an ambient light controller, the electrical power provided to the LED load array via the power control unit is controlled, in indirect proportion to ambient light. Accordingly, the light-generating system **122** has complex dimming and startup functionality, thereby providing improved efficiency in mornings, evenings, and at other times when the ambient light is changing.

An alternative embodiment of the light-generating system **220** of the invention is shown in FIG. **5**. As can be seen in FIG. **5**, in the light-generating system **220**, a LED load array **222** is mounted on a side **268** of the heat sink **224**. The light-generating system **220** is intended for use where the light fixture (not shown) in which the light-generating system is to be used positions the light-generating system so that light is directed from the light-generating system in a direction which is substantially transverse to the axis (identified as "X" in FIG. **5**) defined by the heat sink **224**, e.g., for "cobra" style streetlights or parking lot lights.

An alternative embodiment of a light-generating system **320** of the invention is illustrated in FIGS. **6**-**8**B. As can be seen in FIG. **6**, the light-generating system **320** includes a base **369** with a heat sink **324** on which a power control unit **328** (including a printed circuit board **370**) is positioned. Preferably, the light-emitting diodes **323** in a LED load array **322** are positioned on the printed circuit board **370**, at suitable intervals along the length of the base **369**. The light-generating system **320** also includes end caps **372** positioned at each end of the base **369**.

Each end cap **372** preferably includes a body portion **373** positioned to assist in holding a cover **374** in position. Preferably, each end cap **372** includes two prongs **378**, **380** extending from the body portion **373**. The prongs **378**, **380** are formed to be receivable in the holes in a typical light fixture for a fluorescent light tube (not shown). It will be understood that the prongs **378**, **380** are made of an electrical insulator (e.g., a suitable plastic, such as polyethylene), and so the prongs **378**, **380** do not conduct electricity. The connection of the system **320** to a power source (not shown) preferably is via wires **382**.

Preferably, the light-generating system **320** is formed to fit into a conventional fluorescent tube light fixture. Accordingly, the heat sink **324** is elongate, and the LED load array **322** is positioned on the PCB **370** which preferably is secured directly to the heat sink **324** so that the LED load array **322** will direct light downwardly from the conventional light fixture, when the system **320** is positioned in the conventional fixture (not shown) and energized. As can be seen in FIG. **7**, the base **369** preferably includes a finned portion **326**, with fins **345** extending outwardly, for heat dissipation. The heat sink preferably includes substantially flat regions **384**A, **384**B on which the PCB **370** is attachable. It is preferred that the base **369** also includes a channel **385** positioned centrally along the length of the base **369**, between the flat regions **384**A, **384**B. The channel **385** is at least partially defined by walls **393**, **394**, **395** (FIG. **7**). Certain elements of the power control unit **328** (e.g., the microprocessor) preferably are positioned in the channel **385**, to protect such elements, and also for dissipation of heat therefrom. The light-emitting diodes **323** preferably are mounted on a strip (not shown) which preferably is also at least partially positioned in the channel **385**, for dissipation of heat therefrom.

Preferably, the base **369** also includes side portions **386** with transverse parts **388** at ends **390** of the side portions **386**. As can be seen in FIG. **6**, the light-generating system **320** includes the substantially transparent cover **374** which is held in position on the heat sink **324** between the side portions **386**. The cover **374** preferably is made of any suitable flexible transparent or translucent material such as those skilled in the art would be aware of. Preferably, the cover **374** is made of a suitable acrylic. However, if the system is to be used in a harsh environment, the cover **374** preferably is made of polycarbonate, which would withstand shocks better than acrylic.

It is also preferred that the cover **374** (also shown in FIGS. **8**A and **8**B) is formed so that it is subjected to tension when folded (as shown in FIG. **8**B) and held between the side portions **386**. Because the cover **374** is subjected to tension when it is held in this way between the side portions **386**, the cover **374** is held in position when the light-generating system **320** is in position in the conventional fluorescent light tube fixture. The cover **374** is also partially held in place on the base **369** by the transverse parts **388**, which engage the cover **374**. (It will be understood that the end caps **372** are intentionally omitted from FIG. **8**A for clarity of illustration.)

In operation, the light-generating system **320** functions generally the same as the system **20**, described above. Input electrical power, if AC, is rectified by the power control unit **328**, and the output electrical power is changed or modified by the power control unit **328** in response to information provided by a thermistor (not shown), which monitors temperature of the heat sink **324** at a predetermined location. Optionally, the light-generating system **320** may additionally include an ambient light controller (not shown), functioning as in the system **120**, described above.

As noted above, the light-generating system **320** preferably is configured to fit into a conventional fluorescent light tube fixture, although the power supply is not provided via such fixture. It will be appreciated by those skilled in the art that the system **320** may be conveniently used to retrofit with LEDs, with minimal rewiring required.

It will be appreciated by those skilled in the art that the invention can take many forms, and that such forms are within the scope of the invention as described above. The foregoing descriptions are exemplary, and their scope should not be limited to the preferred versions provided therein.

I claim:

1. A light-generating system for consuming input electrical power from a power source to generate light, the light-generating system comprising:

a LED load array comprising a plurality of light-emitting diodes, the light-emitting diodes having an operating temperature when energized;

a heat sink on which the LED load array is mounted, the heat sink being adapted for absorbing and dissipating heat energy generated by the light-emitting diodes when energized, the heat sink comprising:

a body portion to which the light-emitting diodes are attached;

a finned portion connected to the body portion, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes, to cool the light-emitting diodes;

a power control unit electrically connected to the power source and the LED load array, for converting the input electrical power to an output electrical power and controlling voltage and current of the output electrical power provided by the power control unit to the LED load array;

a temperature detector subassembly operatively connected to the power control unit, the temperature detector subassembly being adapted for sensing a heat sink temperature of the heat sink at least one predetermined location thereon;

the temperature detector subassembly being adapted to compare the heat sink temperature to at least one preselected temperature within a preselected temperature range, and to transmit a control signal to the power control unit upon determining that the heat sink temperature differs from said at least one preselected temperature by more than at least one preselected minimum difference; and

upon receipt of the control signal, the power control unit changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes such that the heat sink temperature is within the preselected temperature range.

2. A light-generating system according to claim **1** in which the power control unit comprises:

a microprocessor; and

a current sensor, for determining current data associated with the output electrical power and communicating the current data to the microprocessor.

3. A light-generating system according to claim **1** additionally comprising an ambient light controller for controlling the electrical power provided to the LED load array, in indirect proportion to ambient light.

4. A light-generating system according to claim **1** in which:

said at least one preselected temperature comprises an upper limit preselected temperature and a lower limit preselected temperature; and

said at least one preselected minimum difference comprises an upper limit minimum difference and a lower limit minimum difference.

5. A light-generating system according to claim **4** in which, upon the temperature detector subassembly determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range.

6. A light-generating system according to claim **5** in which the control signal causes the voltage of the output electrical power to decrease to an extent required by the control signal.

7. A light-generating system according to claim **4** in which, upon the temperature detector subassembly determining that the heat sink temperature is less than the lower limit preselected temperature by at least the lower limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to increase the output electrical power to raise the heat sink temperature until the heat sink temperature is within the preselected temperature range.

8. A light-generating system according to claim **7** in which the control signal causes the voltage of the output electrical power to increase to an extent required by the control signal.

* * * * *

EXHIBIT B

From: Joe Casper <joecasper@ephesustech.com>
Sent: Tuesday, March 15, 2011 9:18 AM
To: John Johnston
Subject: Re: University and Electronics
Attachments: PastedGraphic-1.tiff

Hi John

March 31st or April 1st look good for me.

Joe

Joe Casper
President and CEO

Ephesus Technologies

Syracuse Technology Garden
235 Harrison Street
Syracuse, NY 13202
www.ephesustech.com
Office: (315) 474-0912
Cell: (315) 720-4727

On Mar 11, 2011, at 12:56 PM, John Johnston wrote:

Hi Joe,

Yes I would have loved to learn more. We had a full plate yesterday with both King+King and with a leasing company that is going to help our customers pay for their lights out of their energy and maintenance savings – it will make it easier for them to say YES!

Maybe we can get together the week of the 28th and possibly go meet C-Speed and/or see the Binghamton projects as well, let me know your schedule on Wednesday the 30th or Friday April 1st and what you would like to do and I can firm plans at my end.

I will be visiting Clarkson on Monday the 21st so I will be sure to mention your names.

Regards
John

From: Joe Casper [mailto:joecasper@ephesustech.com]
Sent: Friday, March 11, 2011 12:26 PM
To: John Johnston
Subject: University and Electronics

Hi John

It was a pleasure meeting with you yesterday. I wish we had more time to further our discussion on our projects we both are exploring…being just down the hallway will be great.

I am interested in exploring with you how we can collaborate to leverage you're lighting technology expertise and our nanotechnology electronics expertise to explore various opportunities and problems we are trying to solve.

I would like to share with you in more depth our flexible graphene project at Binghamton University for electronics and LED lighting applications. Also, share with you our board manufacture partner here in Syracuse and relationship with Clarkson University.

Joe

Joe Casper
President and CEO
<image001.gif>
Syracuse Technology Garden
235 Harrison Street
Syracuse, NY 13202
www.ephesustech.com
Office: (315) 474-0912
Cell: (315) 720-4727

EXHIBIT C

MUTUAL CONFIDENTIALITY AGREEMENT

THIS AGREEMENT is made on 1st of April, 2011 (the "Effective Date"), between ProTerra LED International Inc., ("ProTerra"), an Ontario corporation with offices at 435 Elgin Street in Brantford, ON, N3S 7P5 and, Ephesus Technologies LLC ("Company"), with offices at 235 Harrison Street Syracuse new York and is effective as of the date set forth above. The parties acknowledge the following facts:

A. ProTerra and Company wish to enter into discussions, review, analysis and negotiations related to their respective businesses to determine if there is sufficient mutual interest by the parties regarding a possible collaboration and/or business relationship in ProTerra LED lighting products ("the Project").

B. In order to evaluate and, if appropriate, to proceed with the Project, each of the parties may disclose (the "Disclosing Party") to the other party (the "Receiving Party") certain Confidential Information (as defined below).

In consideration of the above premises and the covenants hereinafter set forth, the parties agree as follows:

1. **Confidential Information.** "Confidential Information" means information related to the business of the Disclosing Party which is proprietary and/or confidential to the Disclosing Party or its customers, suppliers or other business partners including, without limitation, technical and nontechnical data related to the designs, inventions, techniques, processes, prototypes, undisclosed patents pending, finances, business plans, actual or potential customers and suppliers, existing and future products and employees of the Disclosing Party whether marked confidential or not, in any form or media, together with all analyses, compilations, studies or documents prepared by the Receiving Party whether prepared or received before or after the Effective Date. The parties further agree that any information obtained by the Receiving Party by way of observation or study at the facilities of the Disclosing Party, and which does not otherwise fall within the exclusions of paragraph 2 below, shall be considered Confidential Information for the purposes of this Agreement. Confidential Information shall also specifically include the terms of this agreement and neither party shall disclose the existence of this Agreement or the Project other than as expressly agreed in writing. The Receiving Party shall not copy, in whole or in part, reverse engineer, decompile or disassemble any computer software that forms part of Confidential Information.

2. **Exclusions from Confidential Information.** The parties agree that, for the purposes of this Agreement, Confidential Information shall not include any information which the Receiving Party can establish: (i) is publicly known through no action on the Receiving Party's part; (ii) by competent written records was known by the Receiving Party prior to receipt from the Disclosing Party; (iii) has been rightfully received by the Receiving Party from a third party without restriction on disclosure and without breach of an obligation of confidentiality running directly or indirectly to the Disclosing Party; or (iv) by competent written records was independently developed by the Receiving Party without reference to, or reliance on, any information which would otherwise be Confidential Information hereunder. In addition, it shall not be considered a breach of the obligations of this Confidentiality Agreement if the Receiving Party discloses Confidential Information to that extent that such information: (a) has been approved for public release by the Disclosing Party's written authorization; or (b) is required to be disclosed by law, or to a competent court, government or regulatory body having the right to same.

3. **Restrictions on Use.** As consideration for having access to or receiving any Confidential Information, the Receiving Party agrees that it shall use the Confidential Information solely in furtherance of the Project and shall make the Confidential Information available solely to employees, agents or independent contractors of the Receiving Party (a) who are directly involved in performing the Project and have a specific need to know such information; and (b) whom the Receiving Party has obligated under a confidentiality agreement to hold the Confidential Information in trust and in strictest confidence. The Receiving Party shall use the same efforts to protect the confidentiality of the Confidential Information as it uses to protect its own Confidential Information and, in any event, no less than a reasonable standard of care. The Receiving Party shall not disclose or disseminate, or permit any of its employees to disclose or disseminate, the Confidential Information to any third party without the other's prior written consent.

INITIAL

4. **Return of Confidential Information.** Upon the termination of this Agreement, or at either party's request, the party in receipt of any Confidential Information shall, on request, deliver to the Disclosing Party all files, documents, computer programs and other media (and all copies and reproductions of any of the foregoing) in its possession or control to the extent same contain Confidential Information. Upon the request of either party, the Receiving Party shall certify in writing that all materials containing Confidential Information (including all copies thereof) have been returned to the Disclosing Party.

5. **Term and Termination.** This Agreement shall become effective on the Effective Date first set forth above and shall terminate upon the expiration of two (2) years from the Effective Date unless earlier terminated by either party at any time on written notice to the other. Notwithstanding any termination of this Agreement the obligations and restrictions on the Receiving Party under paragraph 3 above shall survive until such time as the information in question otherwise falls into one of the exclusions from "Confidential Information" set out in paragraph 2.

6. **No Warranty or License.** This Agreement does not require either party to disclose any Confidential Information and any Confidential Information provided hereunder is provided strictly on an "as is" basis without any warranty or guarantee. All Confidential Information shall remain the sole property of the party disclosing such information. No license to either party of any trademark, patent, copyright or any other intellectual property right is either granted or implied by this Agreement or any disclosure hereunder.

7. **Due Diligence.** The Receiving Party shall not directly or indirectly contact any shareholders, officers, employees, affiliates, agents, lending institutions, customers or suppliers of the Disclosing Party in connection with the Project without the prior written consent of the Disclosing Party.

8. **Non Solicitation.** In consideration of the Confidential Information being furnished to a Receiving Party, the Receiving Party hereby agrees that for a period of two years from the date hereof, it shall not directly or indirectly solicit, entice, hire or engage any of the officers, employees, full-time, part-time or independent contractors or any direct or indirect sales representatives or agents from time to time of the Disclosing Party.

9. **Injunctive Relief.** The parties agree that disclosure or use of Confidential Information contrary to this Agreement may cause the disclosing party irreparable harm, for which damages may not be adequate compensation. Therefore, the parties agree that a party seeking to enforce this Agreement may be entitled to equitable relief, including an injunction, in order to stop any breach or threatened breach of this Agreement.

10. **Governing Law.** This Agreement is governed by the laws of Ontario, excepting its choice of law provisions. The parties hereby agree to irrevocably submit to the exclusive jurisdiction of the courts of the Province of Ontario in respect of all legal proceedings arising out of this Agreement.

11. **Corporate Affiliates.** This Agreement is intended to encompass the Affiliates (as defined below) of both parties hereto. Consequently, any Affiliates of a party may disclose Confidential Information to the other party or to the other party's Affiliates, and Affiliates of a party may receive Confidential Information from the other party or the other party's Affiliates. The terms "Disclosing Party" and "Receiving Party", as used herein, shall include Affiliates of the parties with respect to Confidential Information disclosed by or received by an Affiliate, as the case may be. Each party is responsible for a breach of this Agreement by any of its Affiliates, and the party agrees to take all reasonable measures to restrain its Affiliates from prohibited or unauthorized disclosure or use of Confidential Information. For the purposes of this Agreement, an "Affiliate" of a party shall mean any corporation or entity that (a) is controlled, either directly or indirectly, by a party; (b) is under common voting control, either directly or indirectly, with the party; or (c) that controls the party; as the case may be, where "control" means the ability to vote greater than fifty percent (50%) of the outstanding voting securities in such corporation.

12. **No commitment.** The parties understand and agree that discussions hereunder are exploratory only and that no commitment or representation has been made or is made by either party that will result in the development, manufacture, marketing, sale or supply of any product or service by either party for or to the other party whatsoever.

INITIAL

13. **Miscellaneous Provisions.** This Agreement constitutes the entire agreement and understanding between the parties and integrates all prior and contemporaneous discussions between them related to the subject matter hereof. No amendment to this Agreement shall be valid unless it is in writing and signed by both parties. Except for the assignment of this Agreement by either party to any Affiliate or subsidiary company, this Agreement may not be assigned by either party without the prior written consent of the other party. This Agreement shall be binding upon the respective successors and assigns of the parties hereto. No delay or omission by either party in exercising any right under this Agreement shall operate as a waiver of that or any other right. If any provision of this Agreement shall be held invalid or unenforceable for any reason, such invalidity or unenforceability shall attach only such provision and shall not affect or invalidate any other provision of this Agreement. This Agreement shall be governed by and construed in accordance with the laws of the Province of Ontario (excluding its conflicts of law rules) and the federal laws of Canada applicable herein and the parties hereby irrevocably attorn to the non-exclusive jurisdiction of the courts of the Province of Ontario. This Agreement may be executed by way of facsimile or electronic transmission of signed copies which shall be binding upon the parties as if an original.

Executed by the duly authorized representatives of the parties to be effective as of the date set forth above.

ProTerra LED International Inc.	Ephesus Technologies LLC
Shan Jamal President	Joseph Casper President 4/1/2011

INITIAL______

EXHIBIT D

From: Joe Casper <joecasper@ephesustech.com>
Sent: Monday, May 16, 2011 4:03 PM
To: John Johnston
Cc: Brian Abbe
Subject: LED Lighting Products

John, could you bring down and leave behind a few of the lighting products when you visit this week? It would be a big help.... Joe

EXHIBIT E

Ephesus, ProTerra, Group4 Produce the Most Advanced LED Lighting

Today Ephesus Technologies, ProTerra LED, and Group4 Labs have formed a multi-million dollar strategic alliance to develop a new generation of LED devices using GaN-on-Diamond nanotechnology in Syracuse NY.

Ephesus Technologies, cofounders Joe Casper and Brian Abbe, is a Syracuse NY based company that creates innovative high tech products and applications using nanotechnology. Ephesus' mission entails identifying and inserting new technologies that have direct impact on the technology needs of commercial and government enterprises. Ephesus currently employs 7 senior research engineers working on the development of nanotechnologies and Intellectual Property.

ProTerra LED, lead by CEO John Johnston, is a world leading providers of solid state LED lighting solutions and are pioneers in high wattage LED. ProTerra designs and manufactures innovative products that will result in a greener planet, tremendous energy and financial savings plus a much brighter future for all. ProTerra is a Canada based company that has recently established an office in Syracuse.

Group4 Labs, Inc., lead by CEO Felix Ejeckam, is a fabless "extreme materials" company that develops and markets unusual semiconductor materials for use in various markets including high performance RF amplifiers, radar components, and solid-state lighting. Group4 Labs is a Fremont California based company that is in the process of establishing offices in Syracuse.

The formation of this strategic partnership alliance has created a complete integrated solution for the development and manufacturing of LED lighting products. This multi-million dollar operation in Syracuse NY will create discriminating LED lighting technologies that will accelerate new products to market. The development of this new alliance will cultivate business growth, job creation, and regional economic development for Syracuse NY.

Ephesus Technologies and ProTerra LED with the addition of Group4 Labs will develop and deploy a new LED bulb using GaN on Diamond nanotechnology. The new LED bulb will far exceed today's LED performance standards. This new LED technology will consume 20% less power, 40% brighter, produce 50% less heat, and at a cost savings of 15% to the consumer over the best LEDs available on the market today.

This new LED device technology will be deployed into ProTerra's current commercial, home/office, municipal and obstruction lighting products.

EXHIBIT F

From: Joe Casper <joecasper@ephesustech.com>
Sent: Wednesday, June 29, 2011 8:48 PM
To: John Johnston
Subject: Re: Current Non-Publication Patent

John, thank you. I will discuss with Kate on Friday. Joe

On Jun 29, 2011, at 9:11 PM, John Johnston wrote:

> Hi Joe,
>
> These are important documents that Kate will need in order to help us build the next lighting patents for InnovatUS,
>
> Regards
> John
> <filing receipt.pdf><patent specification.pdf><Patent drawings.pdf>

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/813,160	06/10/2010	2828	462	K8000659US1	8	1

CONFIRMATION NO. 6373

34236
VALENTINE A COTTRILL
SUSAN TANDAN
50 QUEEN STREET NORTH, STE. 1020
P.O. BOX 2248
KITCHENER, ON N2H6M2
CANADA

FILING RECEIPT

OC000000042199096

Date Mailed: 06/23/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

John F. Johnston, Paris, CANADA;

Power of Attorney: The patent practitioners associated with Customer Number 34236

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/185,731 06/10/2009

Foreign Applications

If Required, Foreign Filing License Granted: 06/21/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/813,160**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No
**** SMALL ENTITY ****

Title

LIGHT-GENERATING SYSTEM

Preliminary Class

372

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

LIGHT-GENERATING SYSTEM

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/185,731, filed June 10, 2009, and incorporates such provisional application in its entirety by reference.

FIELD OF THE INVENTION

[0002] The present invention is a light-generating system.

BACKGROUND OF THE INVENTION

[0003] As is well known in the art, light-emitting diodes ("LEDs") are more efficient than incandescent light bulbs, i.e., more light is produced per watt by an LED than by an incandescent bulb. Other known electrically-powered light sources, e.g., fluorescent light bulbs, have a number of disadvantages, as is well known in the art. For example, fluorescent light bulbs are required to be replaced relatively frequently. Where they are used in streetlights, this can involve significant expenses.

[0004] LEDs have a number of additional advantages. However, as is well known in the art, LEDs require relatively close control of voltage and current and also heat management. For example, because current through the LED is dependent exponentially on voltage, voltage should be closely controlled. Also, the voltage supplied should be sufficient, at a minimum, to cause current to flow in the proper direction (i.e., from p-type to n-type material). In addition, the ambient temperature of the operating environment can significantly affect the performance of LEDs.

[0005] Although LEDs have certain advantages when compared to incandescent or fluorescent bulbs (e.g., lower power consumption, and longer operating time) LEDs also have certain disadvantages, as noted above.

SUMMARY OF THE INVENTION

[0006] For the foregoing reasons, there is a need for an improved light-generating system, in which one or more of the disadvantages of the prior art are addressed or mitigated.

[0007] In its broad aspect, the invention provides a light-generating system for consuming input electrical power from a power source to generate light. The light-generating system includes a LED load array with a plurality of light-emitting diodes, the light-emitting diodes having an operating temperature when energized, and a heat sink on which the LED load array is mounted, the heat sink being adapted for absorbing and dissipating heat energy generated by the light-emitting diodes when energized. The heat sink includes a body portion to which the light-emitting diodes are attached, and a finned portion connected to the body portion, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes, to cool the light-emitting diodes. The system also includes a power control unit electrically connected to the power source and the LED load array, for converting the input electrical power to an output electrical power and controlling voltage and current of the output electrical power provided by the power control unit to the LED load array. In addition, the system includes a temperature detector subassembly operatively connected to the power control unit, the temperature detector subassembly being adapted for sensing a heat sink temperature of the heat sink at one or more predetermined locations thereon.

[0008] The temperature detector subassembly is adapted to compare the heat sink temperature to one or more preselected temperatures within a preselected temperature range, and to transmit a control signal to the power control unit upon determining that the heat sink temperature differs from said at least one preselected temperature by more than a preselected minimum difference.

[0009] Upon receipt of the control signal, the power control unit changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes such that the heat sink temperature is within the preselected temperature range.

[0010] In one of its aspects, the preselected temperature includes an upper limit preselected temperature, and the preselected minimum difference includes an upper limit minimum difference.

[0011] In another aspect, upon the temperature detector subassembly determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range.

[0012] In yet another aspect, the control signal causes the voltage of the output electrical power to decrease to an extent required by the control signal.

[0013] In yet another of its aspects, the power control unit of the invention includes a microprocessor and a current sensor, for determining current data associated with the output electrical power and communicating the current data to the microprocessor.

[0014] In another aspect, the invention additionally includes an ambient light controller for controlling the electrical power provided to the LED load array, in indirect proportion to ambient light intensity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The invention will be better understood with reference to the attached drawings, in which:

[0016] Fig. 1A is an isometric view of an embodiment of a light-generating system of the invention;

[0017] Fig. 1B is a side view of the light-generating system of Fig. 1A;

[0018] Fig. 2 is an exploded view of the light-generating system of Fig. 1A;

[0100] Fig. 3A is a plan view of a bottom plate subassembly of the light-generating system of Fig. 1A, drawn at a larger scale;

[0019] Fig. 3B is a schematic illustration of the light-generating system of Fig. 1A;

[0020] Fig. 4A is a schematic diagram illustrating the light-generating system of Figs. 1A-3;

[0021] Fig. 4B is a schematic diagram illustrating an alternative embodiment of the light-generating system of the invention;

[0022] Fig. 5 is a schematic illustration of another alternative embodiment of the light-generating system of the invention;

[0023] Fig. 6 is an isometric view of an alternative embodiment of the light-generating system of the invention, drawn at a smaller scale;

[0024] Fig. 7 is an end view of a base of the light-generating system of Fig. 6, drawn at a larger scale;

[0025] Fig. 8A is a side view of selected elements of the light-generating system of Fig. 6, drawn at a smaller scale; and

[0026] Fig. 8B is an end view of a cover of the light-generating system of Fig. 6, drawn at a larger scale.

DETAILED DESCRIPTION

[0027] In this specification and in the claims that follow, "LED" means a light-emitting diode. In the attached drawings, like reference numerals designate corresponding elements throughout. Reference is first made to Figs. 1A-4A to describe an embodiment of a light-generating system of the invention indicated generally by the numeral 20. The light-generating system 20 is for consuming input electrical power from a power source (not shown) to generate light. Preferably, the light-generating system 20 includes a LED load array 22 with a number of light-emitting diodes 23, which have an operating temperature when energized. The system 20 also preferably includes a heat sink 24 on which the LED load array 22 is mounted. The heat sink 24 is adapted for absorbing and dissipating heat energy generated by the light-emitting diodes 23, when they are energized. It is preferred that the heat sink 24 includes a body portion 25 to which the light-emitting diodes 23 are attached, and a finned portion 26 connected to the body portion 25, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes 23, to cool the light-emitting diodes 23. In addition, the system 20 preferably includes a power control unit 28 electrically connected to the power source and the LED load array 22, for converting the input electrical power to an output electrical power, and for controlling voltage and current of the output electrical power provided by the power control unit 28 to the LED load array 22. In one embodiment, the system 20 preferably also includes a temperature detector subassembly 30 operatively connected to the power control unit 28. The temperature detector subassembly 30 is adapted for sensing a heat sink temperature of the heat sink 24 at a predetermined location thereon. As will be described, the temperature detector subassembly 30 preferably is also adapted to compare the heat sink temperature to one or more preselected temperatures within a preselected temperature range, and to transmit a control signal to the power control unit 28 upon determining that the heat sink temperature differs from the preselected temperature by one or more preselected minimum differences. Upon receipt of the control signal, the power control unit 28 changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes so that the heat sink temperature is within the preselected temperature range.

[0028] As can be seen in Figs. 1A-3A, in one embodiment, the body portion 25 of the heat sink 24 preferably includes first and second end plates 32, 34 to which the finned portion 26

is attachable (Fig. 2). Preferably, the end plates 32, 34 are substantially round in plan view thereof, with substantially the same diameter. As shown in Fig. 2, it is preferred that the finned portion 26 includes first and second parts 36, 38 which, when attached to the end plates 32, 34, define a generally cylindrical shape overall. Each of the first and second parts 36, 38 includes an interior surface 40, 42 (Fig. 2). It will be understood that, when the heat sink 24 is assembled, the interior surfaces 40, 42 and the end plates 32, 34 at least partially define a cavity 44 in which certain elements (e.g., the power control unit 28) are positionable. For instance, as schematically illustrated in Fig. 3B, the power control unit 28 preferably is mounted on one or more of the interior surfaces 40, 42.

[0029] The heat sink 24 preferably includes any suitable heat dissipation means. For example, depending on the application, one or more heat pipes may be suitable. However, it is preferred that the heat sink 24 includes fins 45 which extend outwardly from the finned portion 26 for heat exchange with the ambient atmosphere, to dissipate heat to the ambient atmosphere. Preferably, the fins 32 are formed for optimal heat transfer characteristics. It will be appreciated by those skilled in the art that the heat sink preferably is made of material with relatively high thermal conductivity. For example, the heat sink 24 preferably is made of extruded aluminum.

[0030] It is preferred that the power control unit 28 includes a microprocessor 46 and a current sensor 48, for determining current data associated with the output electrical power and communicating the current data to the microprocessor 46 (Fig. 4A).

[0031] The power control unit 28 preferably provides a current-regulated and voltage-regulated power supply to the LED load array 22. Preferably, the components of the power control unit 28 are included in a highly integrated single power/controller board design (i.e., a printed circuit board ("PCB")), which is a microprocessor-based control system that fits within the heat sink 24. In one embodiment, the power control unit 28 and other elements of the light-generating system 20 preferably are adapted for 50W or 100W rated output, as selected by the user. Preferably, the power control unit 28 is set for either 50W or 100W when it is manufactured. This arrangement reduces manufacturing costs. Other possible power outputs will occur to those skilled in the art.

[0032] It is also preferred that the system 20 includes a connector 50, for electrically connecting the LED load array 22 to the power control unit 28. The connector 50 preferably is adapted for quick connection and disconnection, to permit relatively quick replacement of a used LED load array 22.

[0033] The light-generating system 20 preferably includes continuous diagnostics for supply, lamp load condition and system functionality. The power measurement and control capability of the power control unit 28 leads to a relatively longer operational life of the LED load array 22.

[0034] Preferably, the microprocessor 46 is for monitoring and controlling various aspects of the performance of the power control unit 28 and/or the light-generating system 20 overall. In particular, the microprocessor 46 receives data about the current and voltage provided to the LED load array 22, compares such measured current and voltage to rated current and voltage, and initiates appropriate action if the measured current and voltage vary from the rated values therefor by more than predetermined differences respectively. Preferably, the output electrical power is controlled via pulse width modulation. It is preferred that voltage is monitored within the microprocessor 46. Current preferably is sensed by the sensor 48, and data in this regard is provided to the microprocessor 46. The microprocessor 46 then directs the pulse lengths accordingly. The microprocessor 46 continuously processes such data at very short time intervals.

[0035] The LED driver 28 sets the voltage applied to the LED load array 22 in a variable fashion, where the microprocessor 46 adjusts the voltage slightly up or down within a given range in order to sense the predetermined current flow. The current flow is measured by a very low resistance power resistor (usually 0.1 Ohms) sensing a very small voltage drop across it (in milli-volts). This measurement is then amplified and put on a feedback to the microprocessor 46 so that it can adjust the potential of the pulses it feeds the output to attempt to match the pre-determined voltage drop across the current sensing resistor.

[0036] From the foregoing, it can be seen that the power control unit 28 is used to control the voltage applied to the LED load array 22. However, unlike traditional supplies, an absolute

output voltage is not set, but instead the applied voltage is set relative to the drop across a current-sensing resistor, as described above.

[0037] In addition, the light-generating system 20 has an overall power efficiency of at least 86 percent, a relatively high efficiency. (Prior art units typically average from 70 percent to 75 percent power efficiency.) The light-generating system 20 preferably has the full operational input range of 85-480 VAC.

[0038] In one embodiment, the light-generating system 20 preferably is adapted to automatically shut itself down immediately upon sufficiently unusual conditions being detected. For example, as the system 20 includes elements thereof adapted for measurement of current and voltage, if the current or voltage supplied is not within predetermined ranges, then the system 20 shuts down upon detection of the unusual conditions. If the applied voltage does not remain within its regulation parameters, then the system is shut down. Similarly, if the current supplied by the pulsing is insufficient to power the load, then the system 20 shuts itself down. Insufficient current may indicate that the system has a short circuit condition.

[0039] In addition, the light-generating system 20 preferably includes an automatic recovery function, pursuant to which the system 20 reboots itself if necessary. For instance, in the event of a complete failure of the power supply to the light-generating system 20, the system 20 reboots itself once the power supply is restored.

[0040] In one embodiment, the light generating system 20 preferably includes the temperature detector subassembly 30 (Fig. 4A) operatively connected to the power control unit 28 via a thermal feedback network 52 (Fig. 4A). Those skilled in the art will be aware that the temperature detector subassembly may include various temperature-detecting elements. It is preferred that the temperature-detecting element in the temperature detector subassembly 30 is a thermistor. The temperature detector subassembly 30 is for sensing a temperature of the heat sink 24. If the temperature differs from a preselected temperature by more than a predetermined extent, then the thermistor 30 provides an increasing signal to the power control unit 28, for increasing the electrical power supplied to the LED load array 22, or the thermistor 30 provides a decreasing signal to the power control unit 28, for decreasing the electrical power supplied to the LED load array 22, as the case may be. The thermistor 30 is adapted to take the ambient

temperature into account. Because the thermistor 30 is included in the system 20, a somewhat smaller heat sink 24 may be used than otherwise would be selected for the light-generating system.

[0041] It will be understood that, in practice, the location on the heat sink 24 at which the temperature thereof is detected preferably should be relatively proximal to the light-emitting diodes 23. For instance, it is preferred that the thermistor 30 is connected to the heat sink 24 for detection of the temperature thereof at the end plate 32. Those skilled in the art will appreciate that, in determining the temperatures which trigger the generation of control signals, the thermal conductivity of the heat sink 24 and the distance of the location at which temperature is detected is from the light-emitting diodes is taken into account.

[0042] In general, the power control unit 28 is required to lower the temperature of the heat sink. In one embodiment, the preselected temperature is an upper limit preselected temperature and/or a lower limit preselected temperature. Also, it is preferred that the preselected minimum difference is, when compared to the upper limited preselected temperature, an upper limit minimum difference, and when the operating temperature is compared to the lower limit preselected temperature, a lower limit minimum difference.

[0043] Preferably, upon the temperature detector subassembly 30 determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly 30 sends the control signal to the power control unit 28, to cause the power control unit 28 to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range. The control signal preferably causes the voltage of the output electrical power to be decreased to an extent required by the control signal.

[0044] Preferably, upon the temperature detector subassembly 30 determining that the heat sink temperature is less than the lower limit preselected temperature by at least the lower limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit 28, to cause the power control unit 28 to increase the output electrical power to raise the heat sink temperature until the heat sink temperature is within the preselected

temperature range. The control signal preferably causes the voltage of the output electrical power to be increased to an extent required by the control signal.

[0045] It will be appreciated by those skilled in the art that the light-generating system 20 may be mounted in any suitable manner. Although many alternative arrangements are possible, in one embodiment, the system 20 preferably includes a hook element 54, to enable the system 20 to be suspended by the hook element 54 attached to a suitable part of a building or other structure (not shown). Input electrical power preferably is provided via any suitable means, e.g., a suitable insulated power cord (not shown). As can be seen in Figs. 1A – 2, the system 20 preferably includes a connection box 56 secured to the heat sink 24 in which the wiring (not shown) for connection with outside feed is located. In one embodiment, the hook element 54 is attached to the connection box 56. It is preferred that the system not be mounted directly into a standard socket (e.g., a socket for accepting an E39 base) due to a requirement for a standards body's approval of both the socket and the light-generating system mounted in such socket.

[0046] In use, the system 20 is positioned as required, e.g., suspended by the hook element 54, and the input electrical power is provided to the system 20 via any suitable means therefore. The light-emitting diodes preferably are fitted with one or more suitable lenses (not shown) for any particular application. For example, in view of the distance above a floor at which the light-emitting diodes are positioned, and the area to be illuminated, lenses with certain characteristics would be preferred. Once connected, the input electrical power is provided to the power control unit 28. The power control unit 28 controls the voltage and current of the electrical power which is provided to the LED load array, so that it is within the appropriate parameters for safe operation of the LED load array. Among other things, if the input electrical power is AC, then AC current is rectified (to DC current) by the power control unit. Once the LED load array is operating, the heat sink dissipates heat, to provide a temperature within a pre-determined operating range of the LED load array.

[0047] As described above, the thermistor preferably provides signals to the power control unit 28 to control the voltage of the output electrical power provided to LED load array 22, in order to maintain the heat sink temperature within a predetermined range, in real time.

[0048] The light-generating system 20 is relatively robust, as all wiring and connectors are generally located inside the heat sink 24, except for the power cord or other wiring for connection to an external power source. The heat sink 24 preferably also acts as a heat sink for the power control unit 28. Preferably, the power control unit 28 is attached directly to an interior surface of the heat sink 24, and positioned in the cavity 44 inside the heat sink 24.

[0049] For reliability, it is preferred that the light-omitting diodes 23 are divided into a number of pairs of individual light-emitting diodes connected in series, and the pairs are connected in parallel. For example, in one embodiment, the LED load array 22 preferably includes 54 light-emitting diodes 23 divided into 27 pairs, and the 27 pairs are connected in parallel. This arrangement is intended to result in greater reliability. If one light-emitting diode fails, then only the other light-emitting diode in that pair ceases to function as a result, because only such other light-emitting diode in that pair is connected in series to the failed light-emitting diode.

[0050] In one embodiment, the light-generating system 120 preferably additionally includes an ambient light controller 160 for controlling the electrical power supplied to the LED load array 122, in indirect proportion to ambient light (Fig. 4B). The ambient light controller 160 preferably includes an ambient light sensor 162 and a photo feedback network 164. The sensor 162 notifies the feedback network 164 of changes in ambient light, and this data is provided to the microprocessor 146. The microprocessor 146 is adapted to compare ambient light levels to predetermined light levels and to determine whether additional electrical power is required to be provided to the LED load array 122 (i.e., if ambient light is below a predetermined lower level) or, alternatively, whether the electrical power supplied to the LED load array 122 should be decreased (i.e., if ambient light is greater than a predetermined upper level). (It will be understood that "ambient light" to which a particular light-generating system 120 is exposed would also include, for instance, light produced by the LEDs in other light-generating systems positioned nearby.) Preferably, the power control unit 128 (Fig. 2B) includes the pulse width modulator in the microprocessor 146 for "slowing down" (or, if necessary, "speeding up") the current provided to the LED load array 122, thereby causing the LED load array 122 to provide less or more light, i.e., as required in indirect proportion to the ambient light.

[0051] In short, where the system of the invention includes an ambient light controller, the electrical power provided to the LED load array via the power control unit is controlled, in indirect proportion to ambient light. Accordingly, the light-generating system 122 has complex dimming and startup functionality, thereby providing improved efficiency in mornings, evenings, and at other times when the ambient light is changing.

[0052] An alternative embodiment of the light-generating system 220 of the invention is shown in Fig. 5. As can be seen in Fig. 5, in the light-generating system 220, a LED load array 222 is mounted on a side 268 of the heat sink 224. The light-generating system 220 is intended for use where the light fixture (not shown) in which the light-generating system is to be used positions the light-generating system so that light is directed from the light-generating system in a direction which is substantially transverse to the axis (identified as "X" in Fig. 5) defined by the heat sink 224, e.g., for "cobra" style streetlights or parking lot lights.

[0053] An alternative embodiment of a light-generating system 320 of the invention is illustrated in Figs. 6-8B. As can be seen in Fig. 6, the light-generating system 320 includes a base 369 with a heat sink 324 on which a power control unit 328 (including a printed circuit board 370) is positioned. Preferably, the light-emitting diodes 323 in a LED load array 322 are positioned on the printed circuit board 370, at suitable intervals along the length of the base 369. The light-generating system 320 also includes end caps 372 positioned at each end of the base 369.

[0054] Each end cap 372 preferably includes a body portion 373 positioned to assist in holding a cover 374 in position. Preferably, each end cap 372 includes two prongs 378, 380 extending from the body portion 373. The prongs 378, 380 are formed to be receivable in the holes in a typical light fixture for a fluorescent light tube (not shown). It will be understood that the prongs 378, 380 are made of an electrical insulator (e.g., a suitable plastic, such as polyethylene), and so the prongs 378, 380 do not conduct electricity. The connection of the system 320 to a power source (not shown) preferably is via wires 382.

[0055] Preferably, the light-generating system 320 is formed to fit into a conventional fluorescent tube light fixture. Accordingly, the heat sink 324 is elongate, and the LED load array 322 is positioned on the PCB 370 which preferably is secured directly to the heat sink 324 so that

the LED load array 322 will direct light downwardly from the conventional light fixture, when the system 320 is positioned in the conventional fixture (not shown) and energized. As can be seen in Fig. 7, the base 369 preferably includes a finned portion 326, with fins 345 extending outwardly, for heat dissipation. The heat sink preferably includes substantially flat regions 384A, 384B on which the PCB 370 is attachable. It is preferred that the base 369 also includes a channel 385 positioned centrally along the length of the base 369, between the flat regions 384A, 384B. The channel 385 is at least partially defined by walls 393, 394, 395 (Fig. 7). Certain elements of the power control unit 328 (e.g., the microprocessor) preferably are positioned in the channel 385, to protect such elements, and also for dissipation of heat therefrom. The light-emitting diodes 323 preferably are mounted on a strip (not shown) which preferably is also at least partially positioned in the channel 385, for dissipation of heat therefrom.

[0056] Preferably, the base 369 also includes side portions 386 with transverse parts 388 at ends 390 of the side portions 386. As can be seen in Fig. 6, the light-generating system 320 includes the substantially transparent cover 374 which is held in position on the heat sink 324 between the side portions 386. The cover 374 preferably is made of any suitable flexible transparent or translucent material such as those skilled in the art would be aware of. Preferably, the cover 374 is made of a suitable acrylic. However, if the system is to be used in a harsh environment, the cover 374 preferably is made of polycarbonate, which would withstand shocks better than acrylic.

[0057] It is also preferred that the cover 374 (also shown in Figs. 8A and 8B) is formed so that it is subjected to tension when folded (as shown in Fig. 8B) and held between the side portions 386. Because the cover 374 is subjected to tension when it is held in this way between the side portions 386, the cover 374 is held in position when the light-generating system 320 is in position in the conventional fluorescent light tube fixture. The cover 374 is also partially held in place on the base 369 by the transverse parts 388, which engage the cover 374. (It will be understood that the end caps 372 are intentionally omitted from Fig. 8A for clarity of illustration.)

[0058] In operation, the light-generating system 320 functions generally the same as the system 20, described above. Input electrical power, if AC, is rectified by the power control unit

328, and the output electrical power is changed or modified by the power control unit 328 in response to information provided by a thermistor (not shown), which monitors temperature of the heat sink 324 at a predetermined location. Optionally, the light-generating system 320 may additionally include an ambient light controller (not shown), functioning as in the system 120, described above.

[0059] As noted above, the light-generating system 320 preferably is configured to fit into a conventional fluorescent light tube fixture, although the power supply is not provided via such fixture. It will be appreciated by those skilled in the art that the system 320 may be conveniently used to retrofit with LEDs, with minimal rewiring required.

[0060] It will be appreciated by those skilled in the art that the invention can take many forms, and that such forms are within the scope of the invention as described above. The foregoing descriptions are exemplary, and their scope should not be limited to the preferred versions provided therein.

We claim:

1. A light-generating system for consuming input electrical power from a power source to generate light, the light-generating system comprising:

a LED load array comprising a plurality of light-emitting diodes, the light-emitting diodes having an operating temperature when energized;

a heat sink on which the LED load array is mounted, the heat sink being adapted for absorbing and dissipating heat energy generated by the light-emitting diodes when energized, the heat sink comprising:

a body portion to which the light-emitting diodes are attached;

a finned portion connected to the body portion, for dissipation of heat energy transferred thereto at least partially via conduction from the light-emitting diodes, to cool the light-emitting diodes;

a power control unit electrically connected to the power source and the LED load array, for converting the input electrical power to an output electrical power and controlling voltage and current of the output electrical power provided by the power control unit to the LED load array;

a temperature detector subassembly operatively connected to the power control unit, the temperature detector subassembly being adapted for sensing a heat sink temperature of the heat sink at at least one predetermined location thereon;

the temperature detector subassembly being adapted to compare the heat sink temperature to at least one preselected temperature within a preselected temperature range, and to transmit a control signal to the power control unit upon determining that the heat sink temperature differs from said at least one preselected temperature by more than at least one preselected minimum difference; and

upon receipt of the control signal, the power control unit changes the voltage of the output electrical power, to modulate the performance of the light-emitting diodes such that the heat sink temperature is within the preselected temperature range.

2. A light-generating system according to claim 1 in which:

said at least one preselected temperature comprises an upper limit preselected temperature and a lower limit preselected temperature; and

said at least one preselected minimum difference comprises an upper limit minimum difference and a lower limit minimum difference.

3. A light-generating system according to claim 2 in which, upon the temperature detector subassembly determining that the heat sink temperature is greater than the upper limit preselected temperature by at least the upper limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to decrease the output electrical power to lower the heat sink temperature until the heat sink temperature is within the preselected temperature range.

4. A light-generating system according to claim 3 in which the control signal causes the voltage of the output electrical power to decrease to an extent required by the control signal.

5. A light-generating system according to claim 2 in which, upon the temperature detector subassembly determining that the heat sink temperature is less than the lower limit preselected temperature by at least the lower limit minimum difference, the temperature detector subassembly sends the control signal to the power control unit, for causing the power control unit to increase the output electrical power to raise the heat sink temperature until the heat sink temperature is within the preselected temperature range.

6. A light-generating system according to claim 5 in which the control signal causes the voltage of the output electrical power to increase to an extent required by the control signal.

7. A light-generating system according to claim 1 in which the power control unit comprises:

    a microprocessor; and

    a current sensor, for determining current data associated with the output electrical power and communicating the current data to the microprocessor.

8. A light-generating system according to claim 1 additionally comprising an ambient light controller for controlling the electrical power provided to the LED load array, in indirect proportion to ambient light.

ABSTRACT

A light-generating system including a LED load array having a number of light-emitting diodes, and a heat sink on which the LED load array is mounted. The system also includes a power control unit electrically connected to the power source and the LED load array, for converting input electrical power to output electrical power and controlling voltage and current of the output electrical power provided to the LED load array, and a temperature detector subassembly adapted for sensing a heat sink temperature of the heat sink. The temperature detector subassembly monitors the heat sink temperature and transmits a control signal to the power control unit upon determining that the heat sink temperature differs from a preselected temperature by more than a preselected minimum difference. Upon receipt of the control signal, the power control unit changes the voltage of the output electrical power accordingly.

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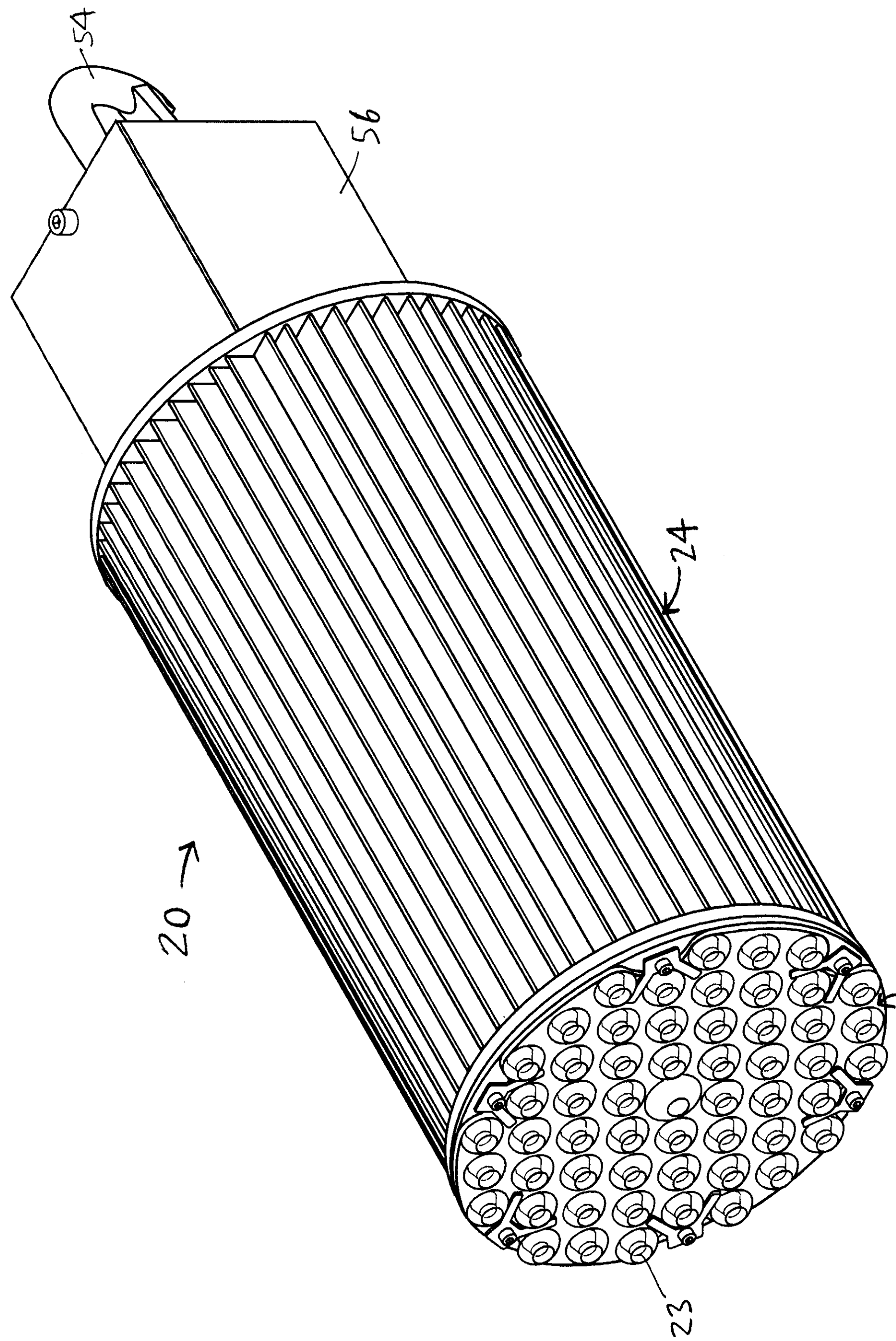


FIG. 1A

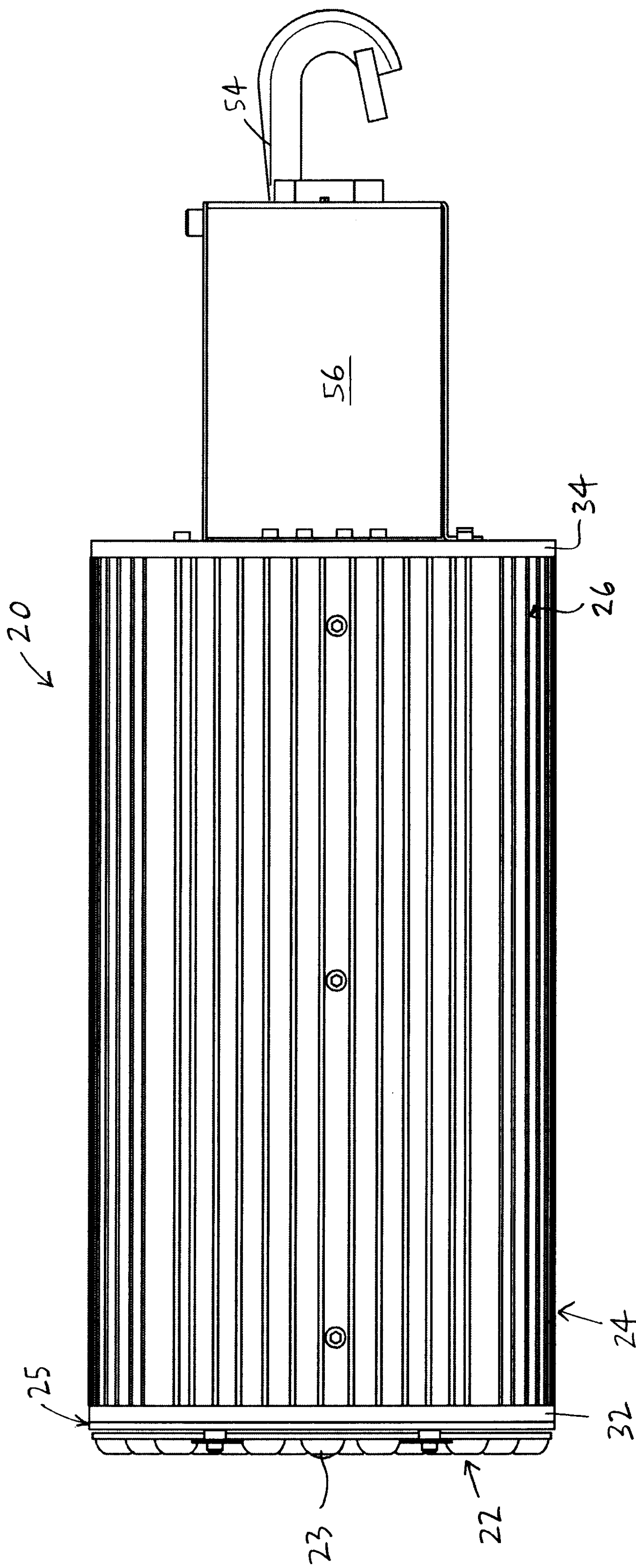


FIG. 1B

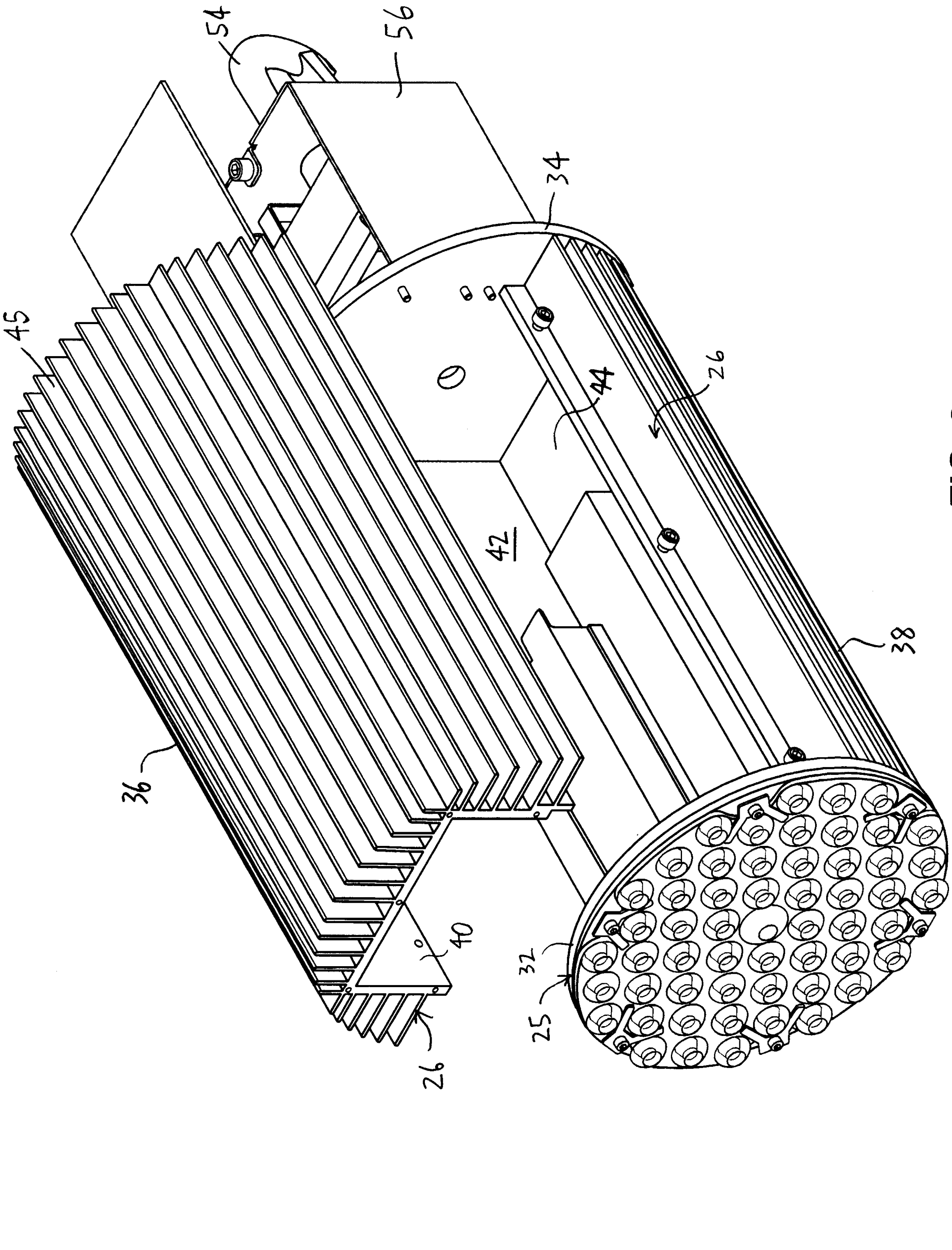


FIG. 2

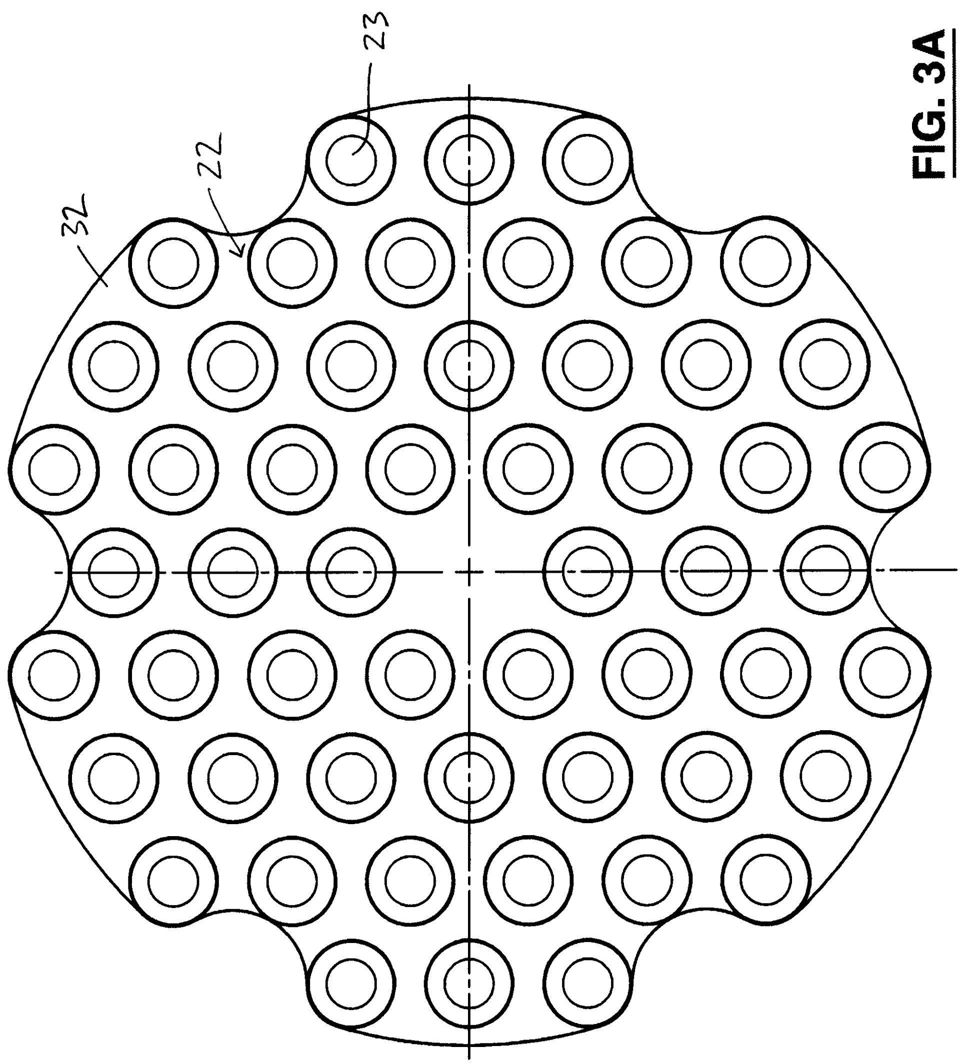


FIG. 3A

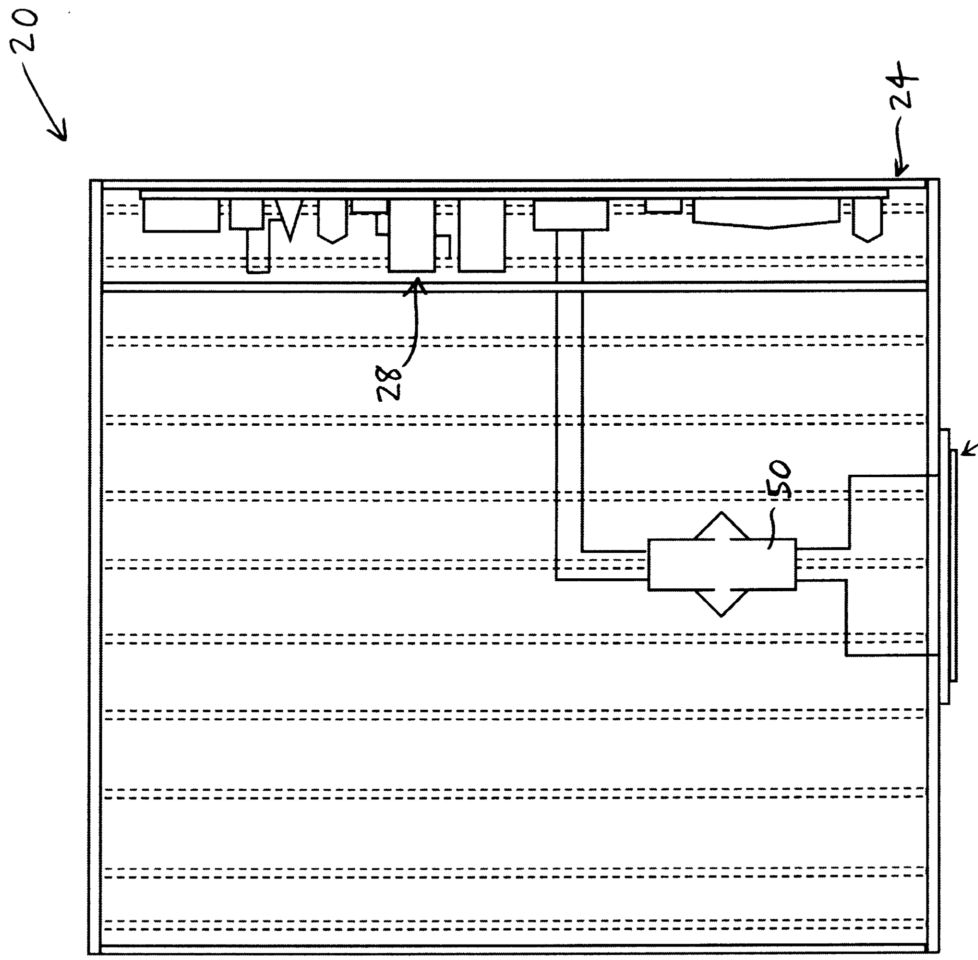


FIG. 3B

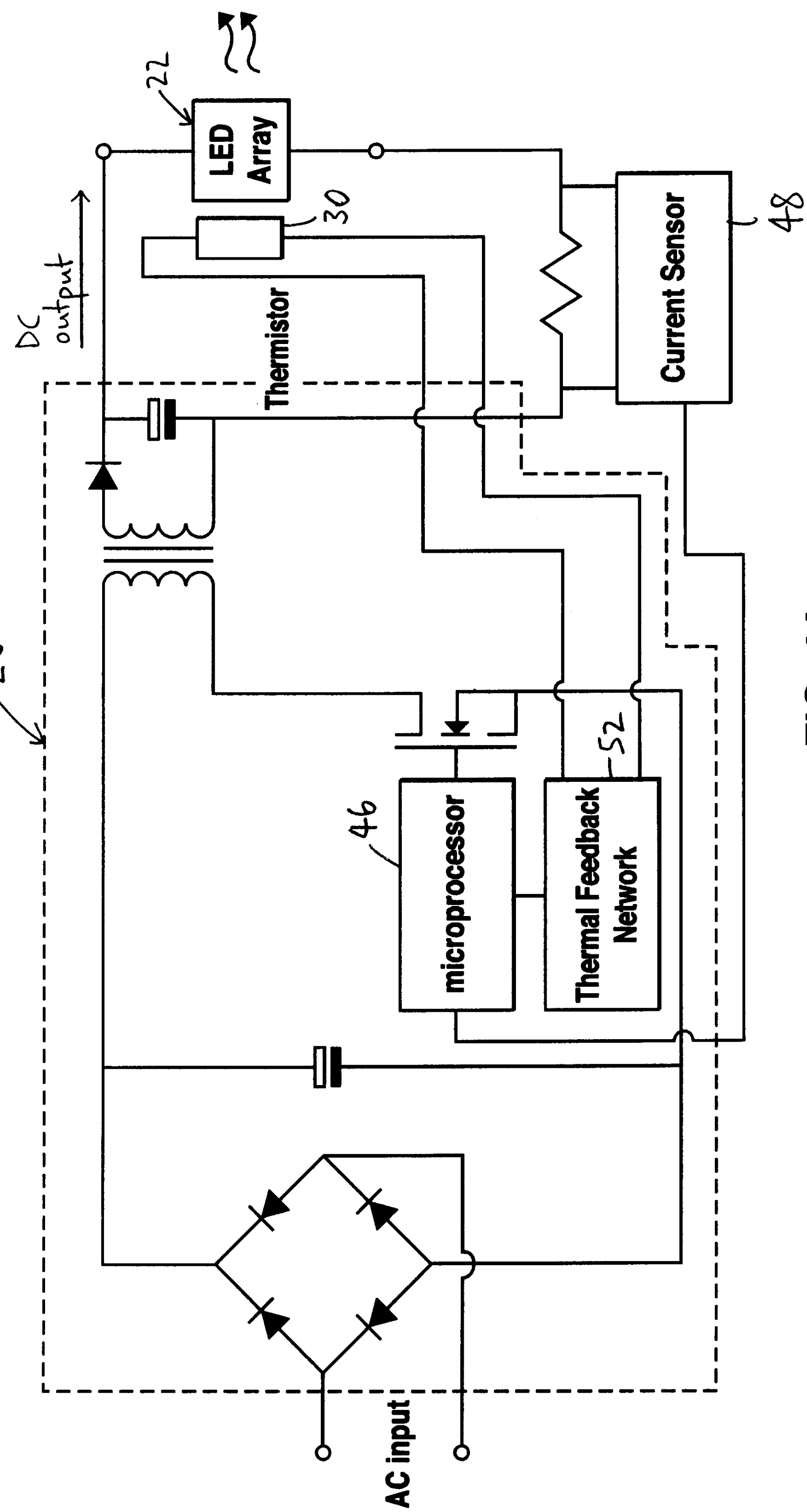

22
LED Array
30
DC output
Thermistor
Current Sensor
48
28
46
microprocessor
52
Thermal Feedback Network
AC input

FIG. 4A

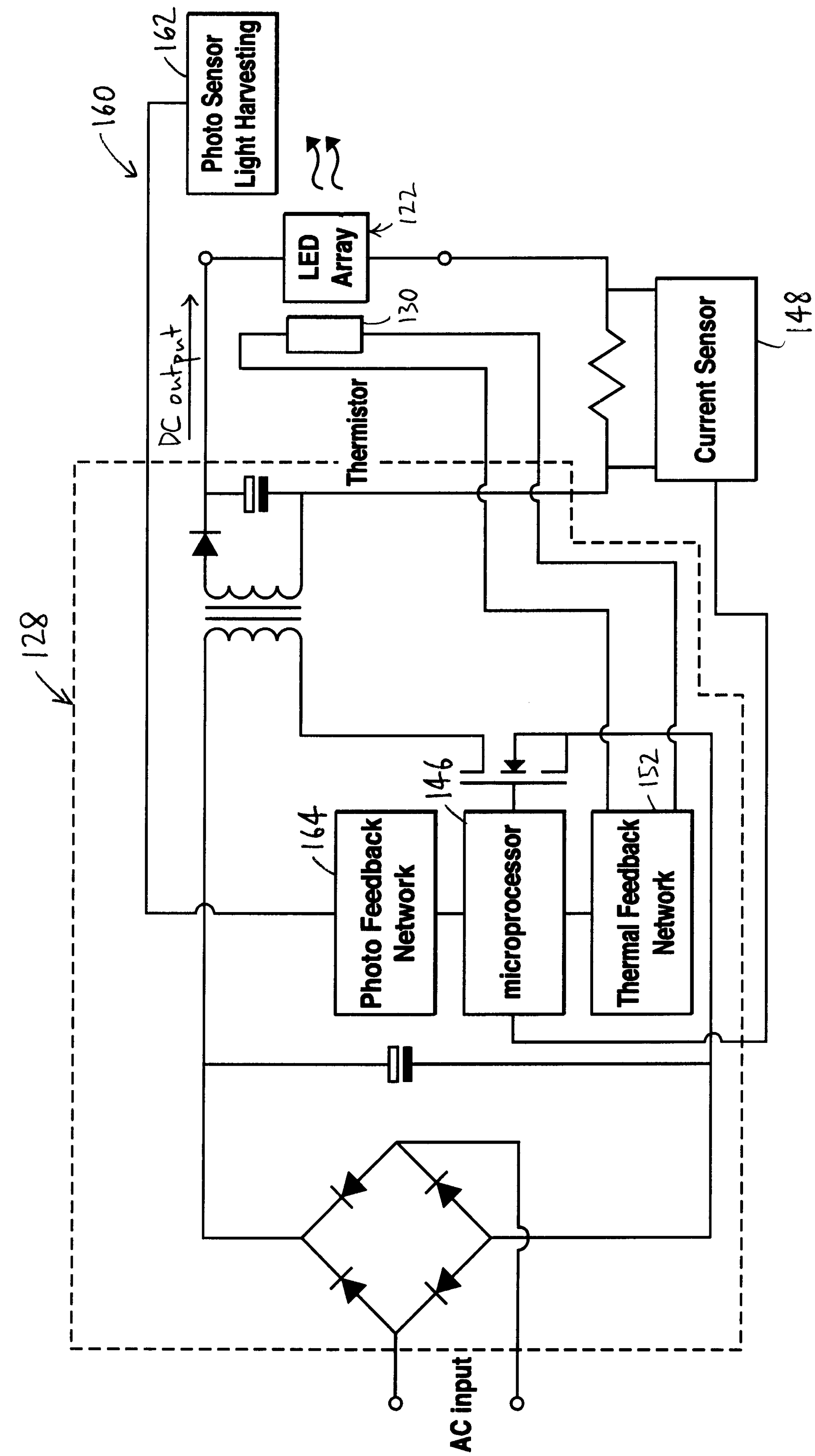


Photo Sensor
Light Harvesting
162
160
LED
Array
122
130
DC output
Thermistor
Current Sensor
148
128
164
146
152
Photo Feedback
Network
microprocessor
Thermal Feedback
Network
AC input

FIG. 4B

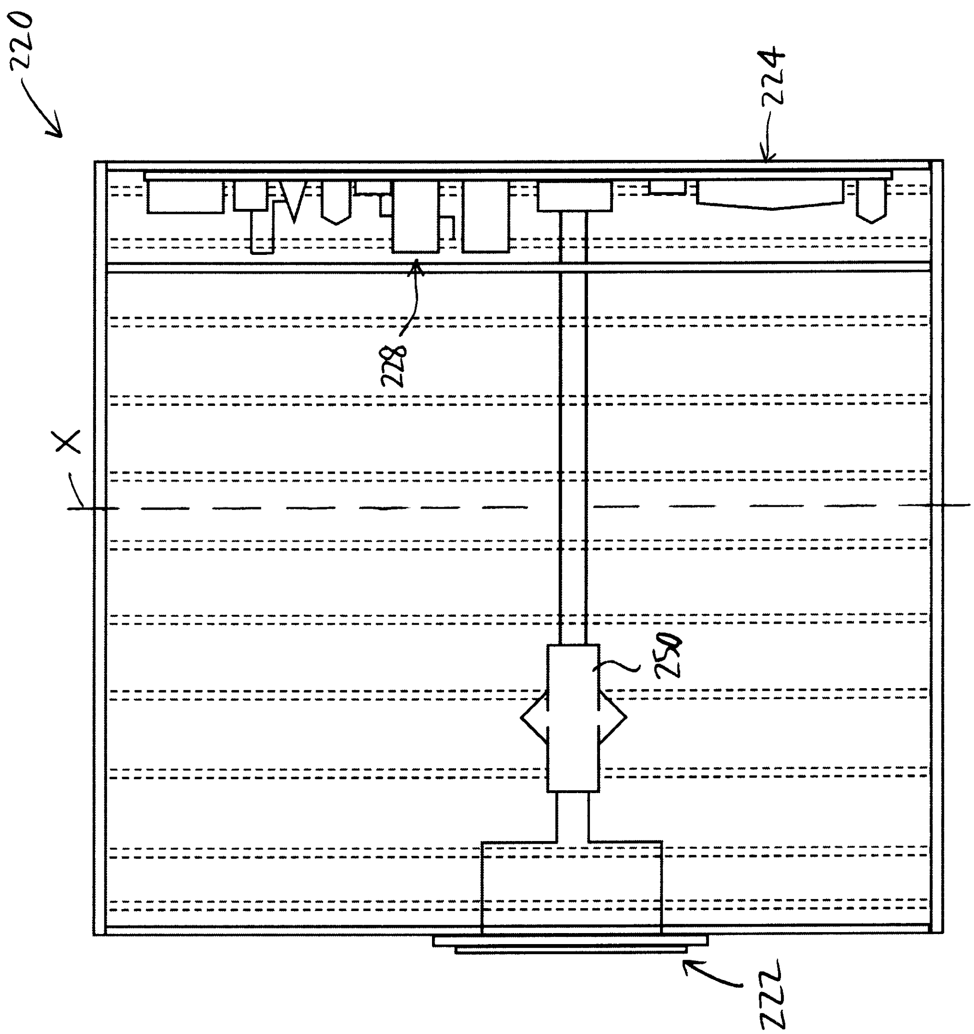


FIG. 5

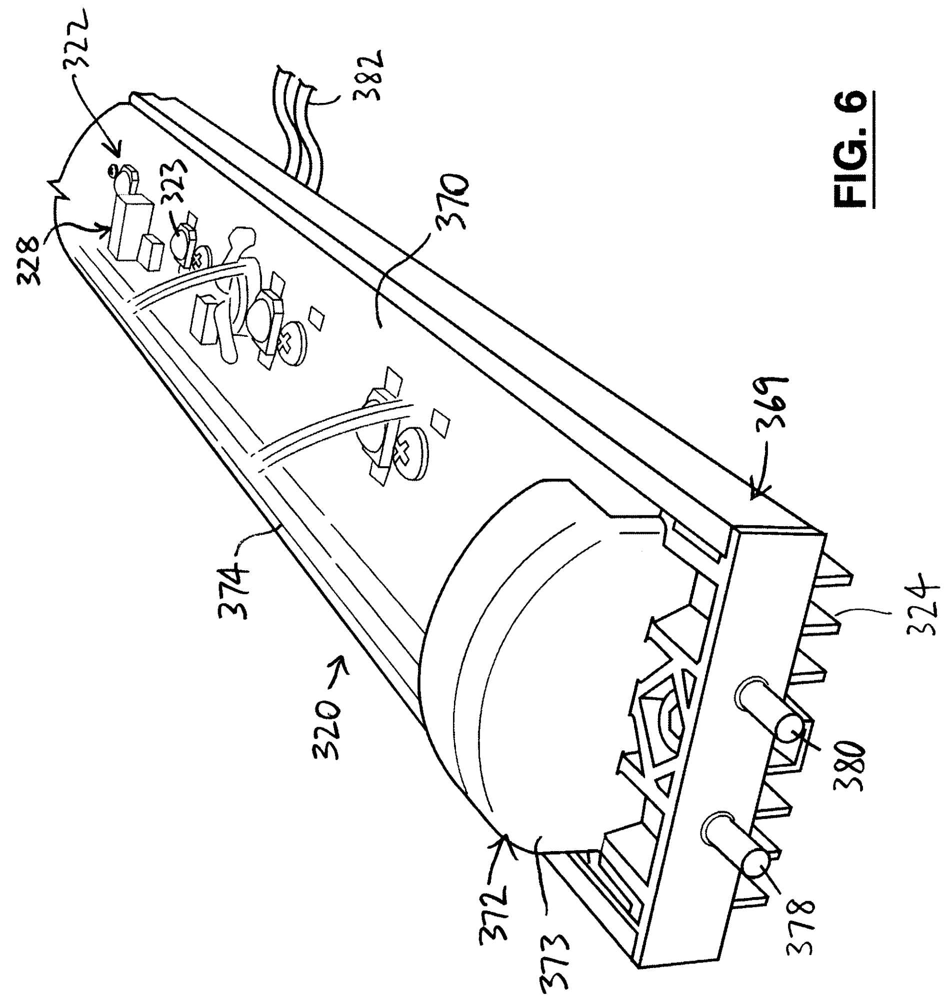
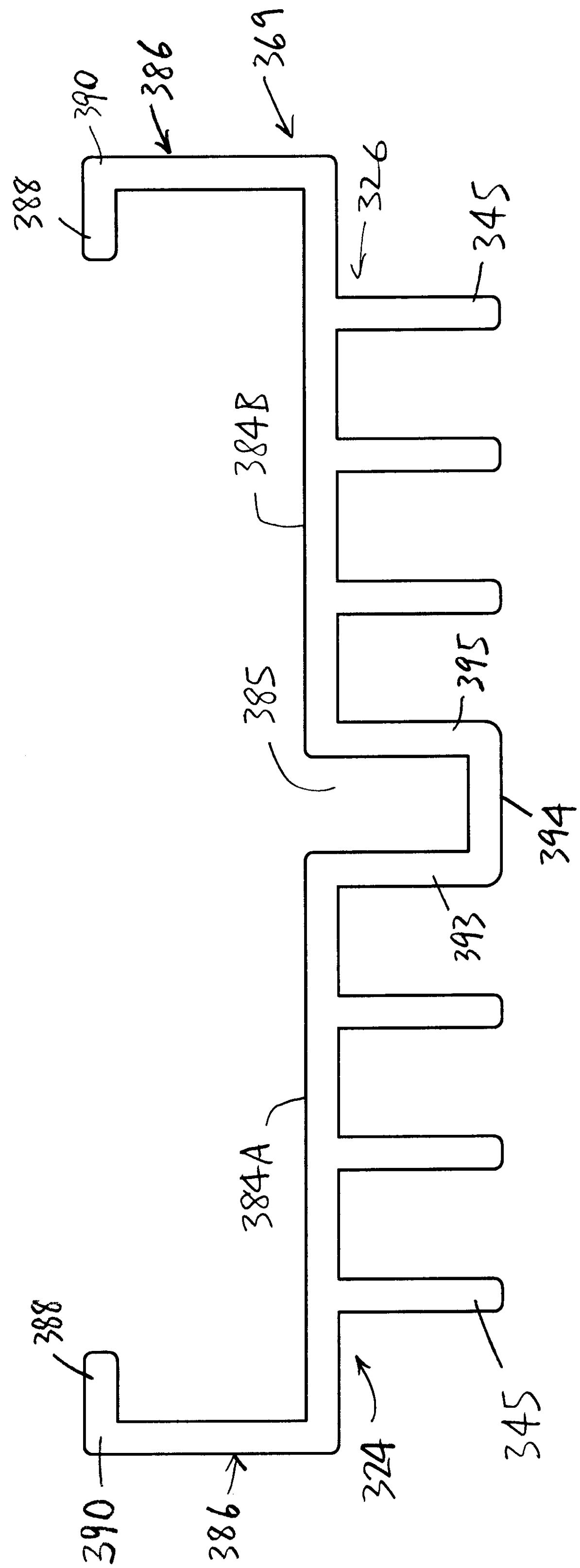


FIG. 6



388
390
386
369
326
345
384B
385
395
394
393
384A
388
345
390
386
324
345

FIG. 7

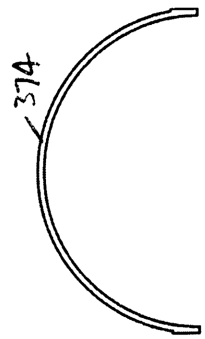


FIG. 8B

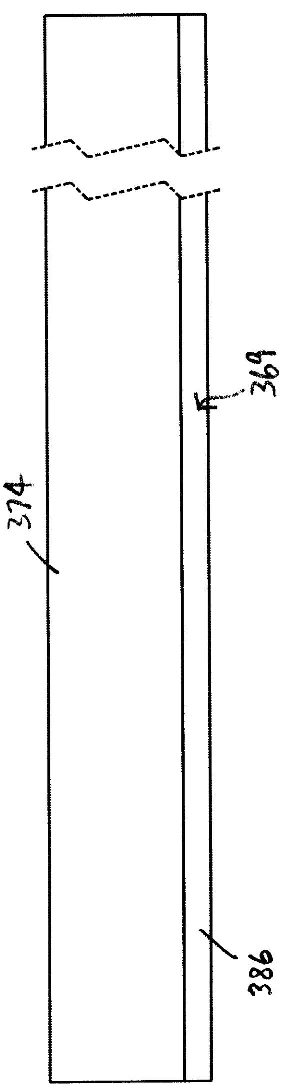


FIG. 8A

EXHIBIT G

US009657930B2

(12) **United States Patent**
Nolan et al.

(10) **Patent No.: US 9,657,930 B2**
(45) **Date of Patent: May 23, 2017**

(54) **HIGH INTENSITY LIGHT-EMITTING DIODE LUMINAIRE ASSEMBLY**

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(73) Assignee: **Ephesus Lighting, Inc.**, Syracuse, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 74 days.

(21) Appl. No.: **14/364,803**

(22) PCT Filed: **Dec. 13, 2012**

(86) PCT No.: **PCT/US2012/069442**

§ 371 (c)(1),
(2) Date: **Jun. 12, 2014**

(87) PCT Pub. No.: **WO2013/090536**

PCT Pub. Date: **Jun. 20, 2013**

(65) **Prior Publication Data**

US 2014/0334149 A1 Nov. 13, 2014

Related U.S. Application Data

(60) Provisional application No. 61/570,072, filed on Dec. 13, 2011, provisional application No. 61/712,226, filed on Oct. 10, 2012.

(51) **Int. Cl.**
F21V 1/00 (2006.01)
F21V 11/00 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F21V 29/2206*** (2013.01); ***F21K 9/60*** (2016.08); ***F21S 2/00*** (2013.01); ***F21V 5/007*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F21V 29/2206; F21V 5/007; F21V 23/009; F21V 29/74; F21V 29/75; F21V 21/30;
(Continued)

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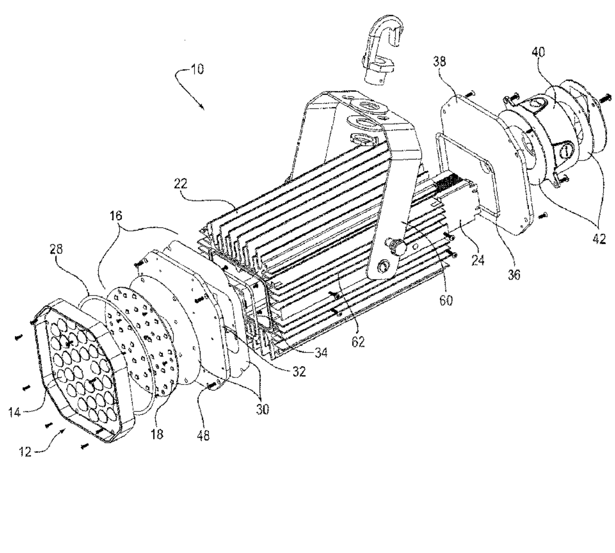
Primary Examiner — Anh Mai
Assistant Examiner — Glenn Zimmerman
(74) *Attorney, Agent, or Firm* — Fox Rothschild LLP

(57) **ABSTRACT**

A low-cost, efficient, high intensity LED luminaire (HILL) assembly for use indoors or outdoors in wet, damp, or dry environments. In various embodiments, the HILL assembly can be powered by a universal AC or a DC electrical supply and can operate in a temperature range from about −40° C. to about +85° C. The HILL assembly can include a lens element comprising one or more concavo-convex lenses; an interchangeable LED module comprising a plurality of LEDs positioned in a LED array; and a heatsink housing containing a power supply for the LEDs. The HILL assembly can optionally comprise a circuit board for the LED
(Continued)



array that employs thermal via technology, a lens with a frosted lip for attenuating the light source as seen from an angle, and/or a sensor for sensing an environmental parameter of interest. Driver circuitry and the LEDs are preferably mounted directly on a common circuit board.

14 Claims, 29 Drawing Sheets

(51) **Int. Cl.**

F21V 29/00	(2015.01)
F21V 5/00	(2015.01)
F21S 2/00	(2016.01)
H05B 33/08	(2006.01)
F21V 23/00	(2015.01)
F21V 29/74	(2015.01)
F21V 29/75	(2015.01)
F21K 9/60	(2016.01)
F21V 21/30	(2006.01)
F21K 9/00	(2016.01)
F21V 15/01	(2006.01)
F21V 21/08	(2006.01)
F21V 23/04	(2006.01)
F21V 29/70	(2015.01)
F21V 29/77	(2015.01)
F21Y 101/00	(2016.01)
F21Y 105/10	(2016.01)
F21Y 115/10	(2016.01)

(52) **U.S. Cl.**
CPC ***F21V 23/009*** (2013.01); ***F21V 29/74*** (2015.01); ***F21V 29/75*** (2015.01); ***H05B 33/0803*** (2013.01); *F21K 9/00* (2013.01); *F21V 15/013* (2013.01); *F21V 21/08* (2013.01); *F21V 21/30* (2013.01); *F21V 23/0464* (2013.01); *F21V 23/0471* (2013.01); *F21V 29/70* (2015.01); *F21V 29/773* (2015.01); *F21Y 2101/00* (2013.01); *F21Y 2105/10* (2016.08); *F21Y 2115/10* (2016.08)

(58) **Field of Classification Search**
CPC F21V 15/013; F21V 21/08; F21V 23/0464; F21V 23/0471; F21V 29/70; F21V 29/773; F21S 2/00; H05B 33/0803; F21K 9/50; F21K 9/00; F21K 9/60; F21Y 2101/02; F21Y 2105/001; F21Y 2101/00; F21Y 2105/01; F21Y 2115/10
USPC 362/235, 294
See application file for complete search history.

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* cited by examiner

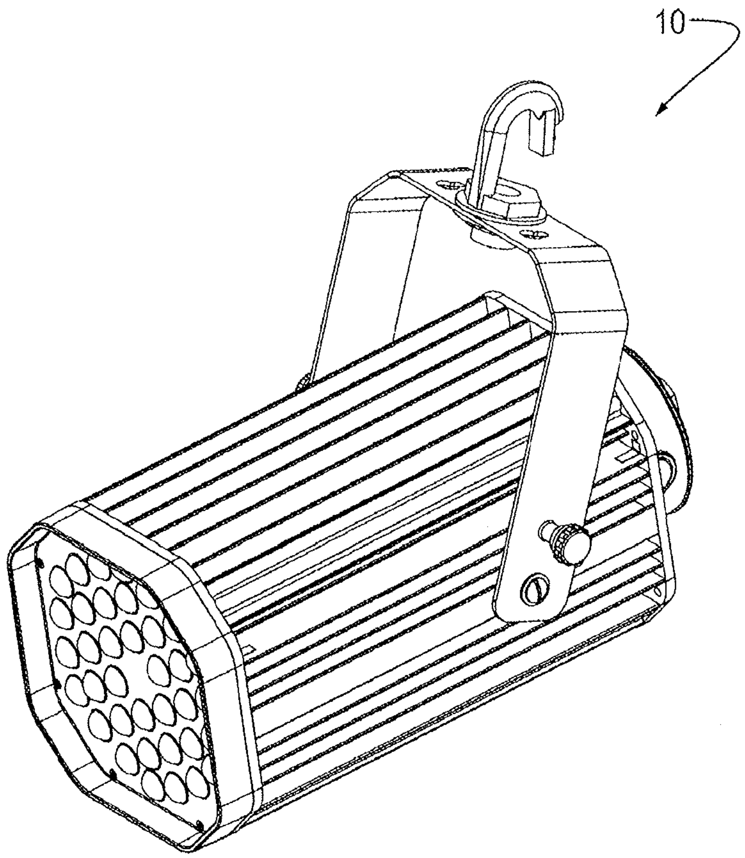


FIG. 1

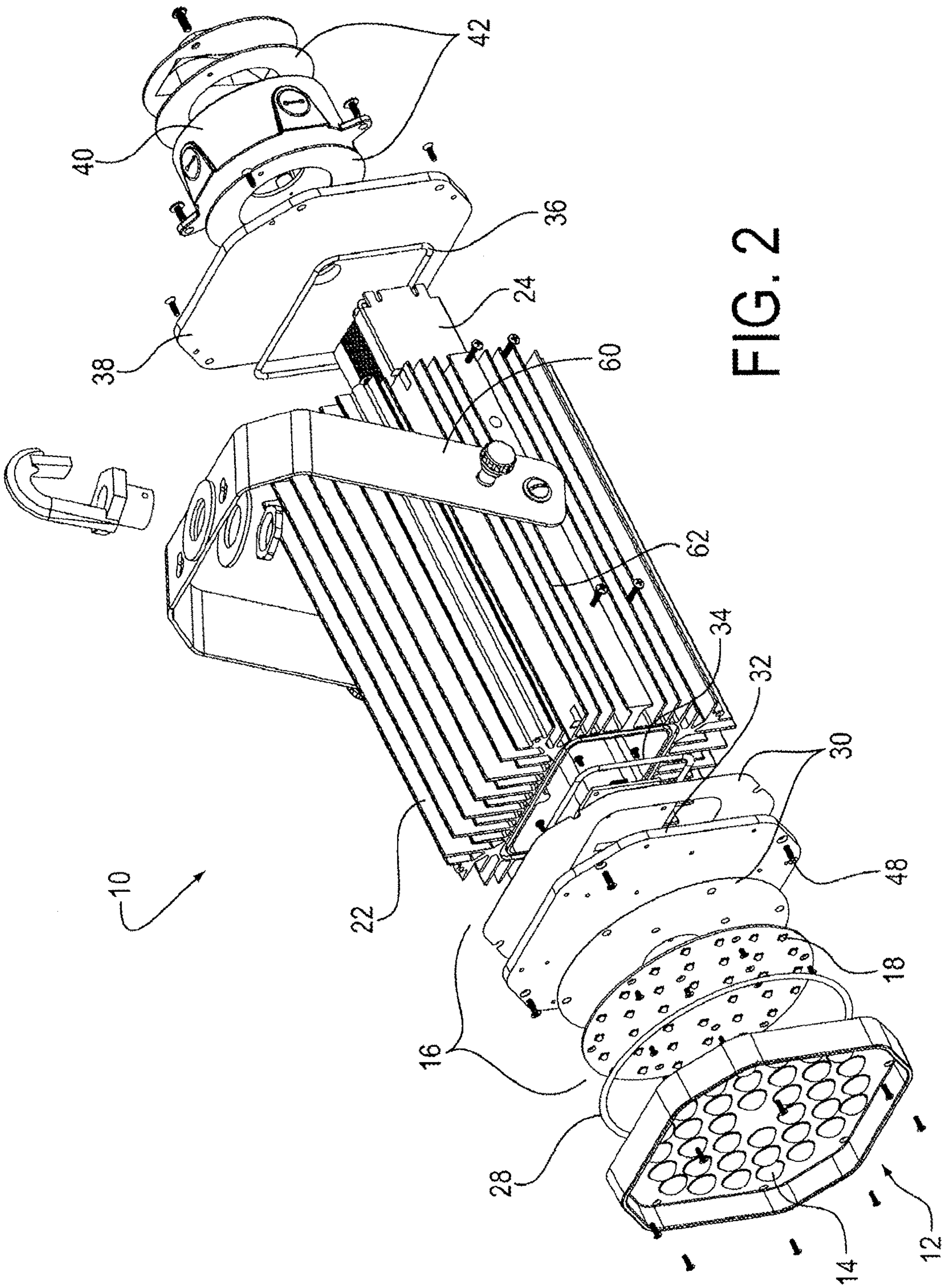


FIG. 2

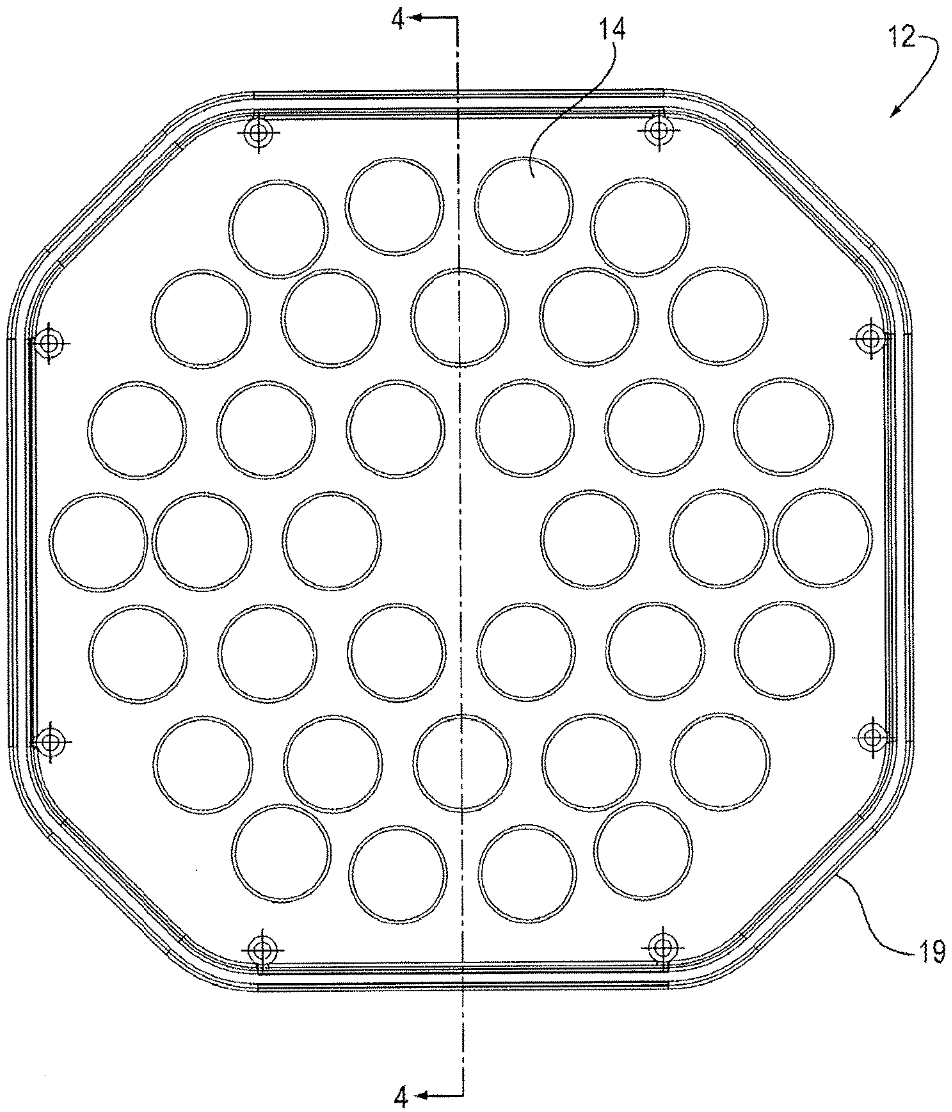


FIG. 3

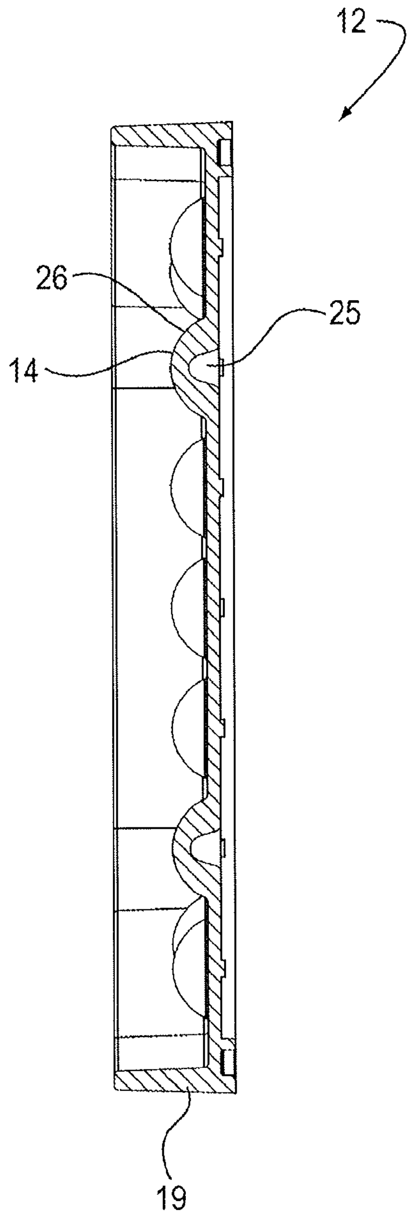


FIG. 4

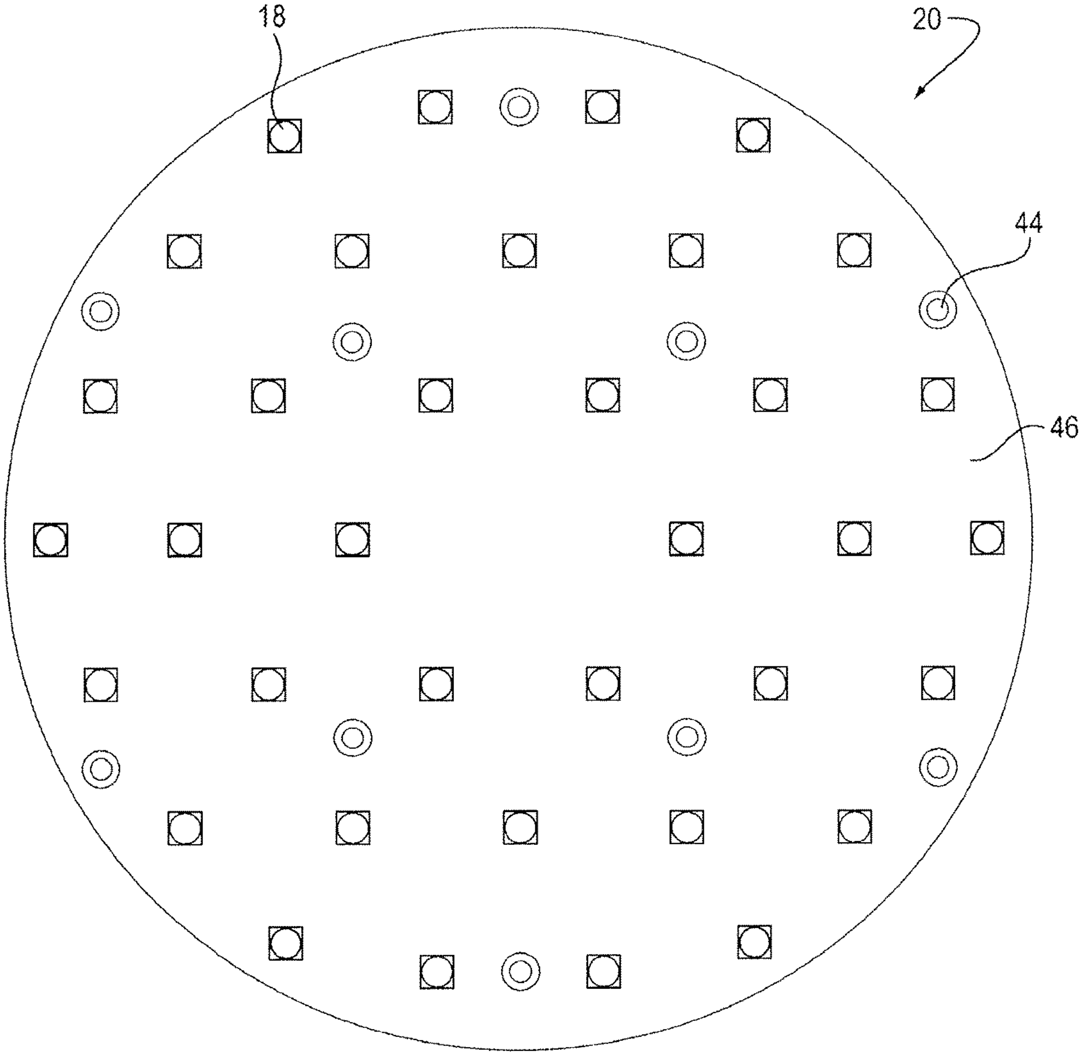
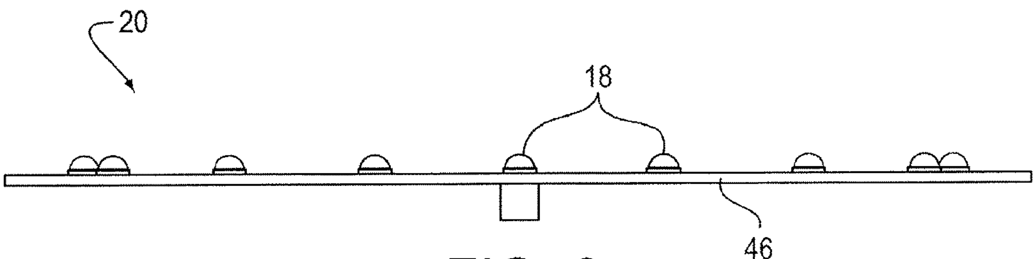


FIG. 5



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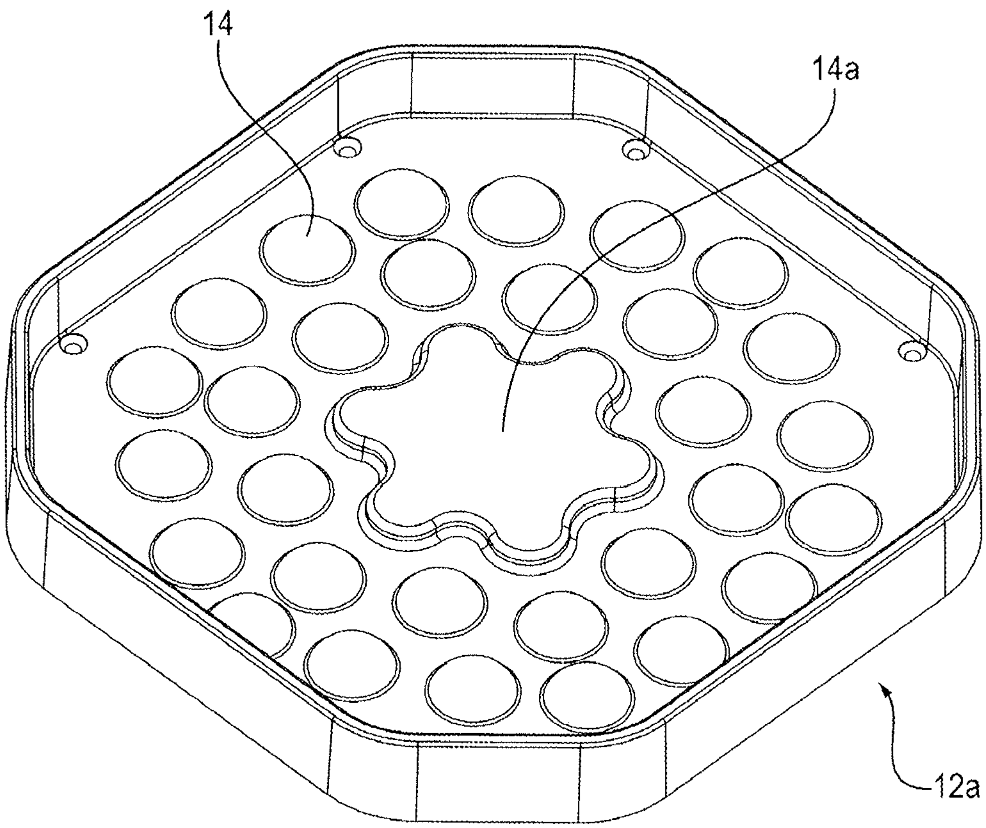


FIG. 7

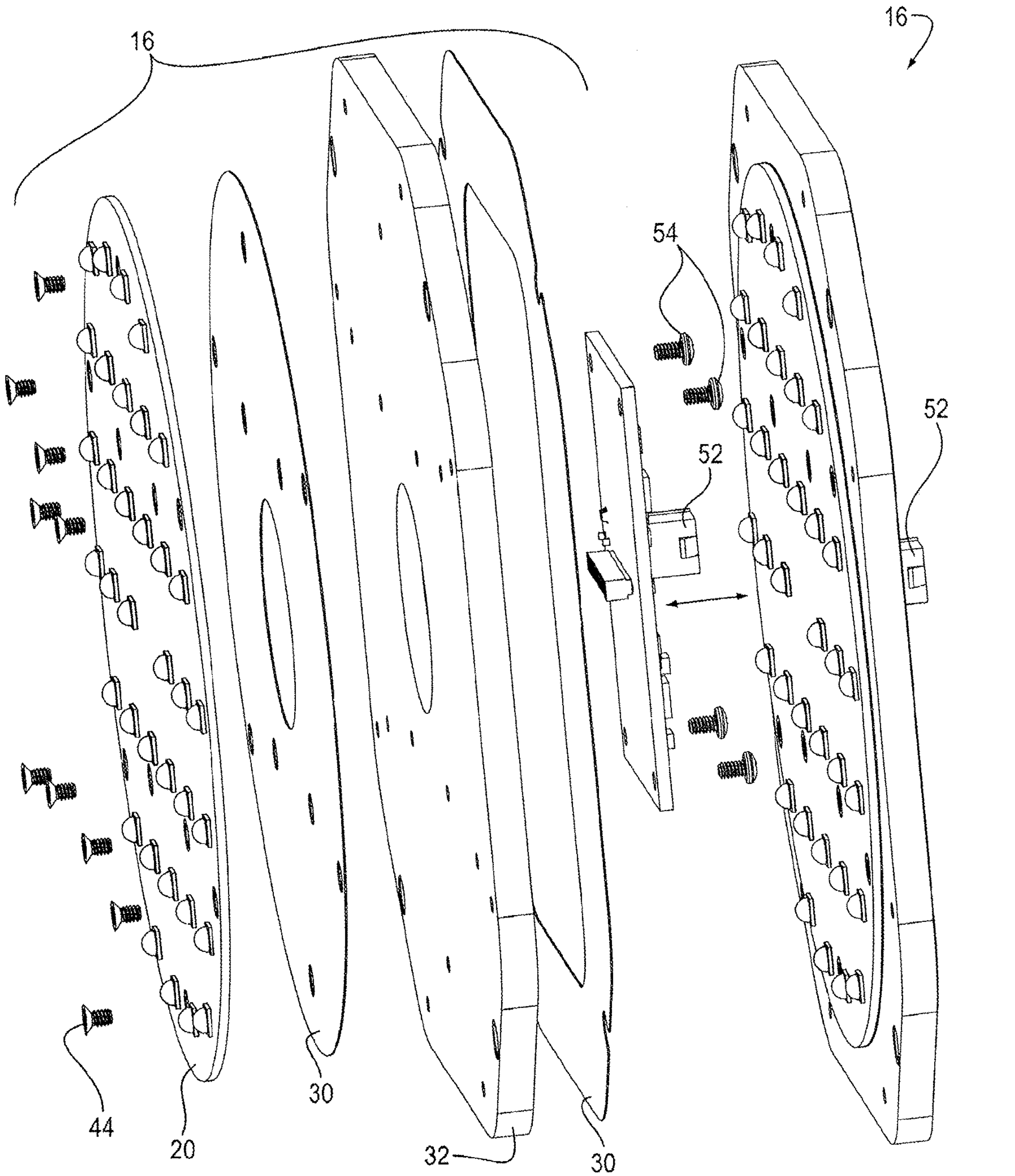


FIG. 8

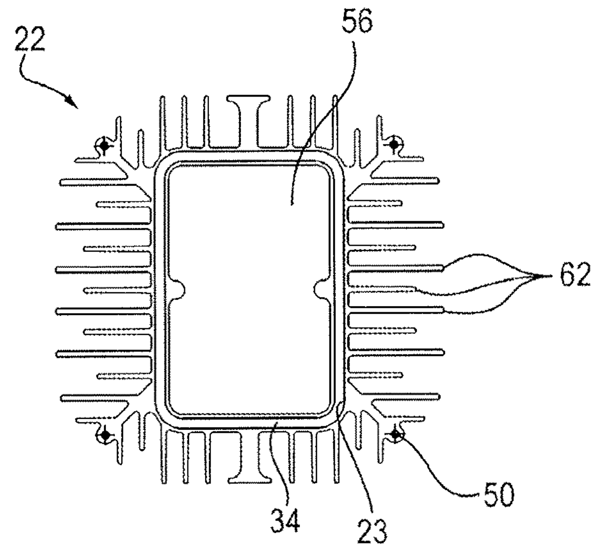


FIG. 9

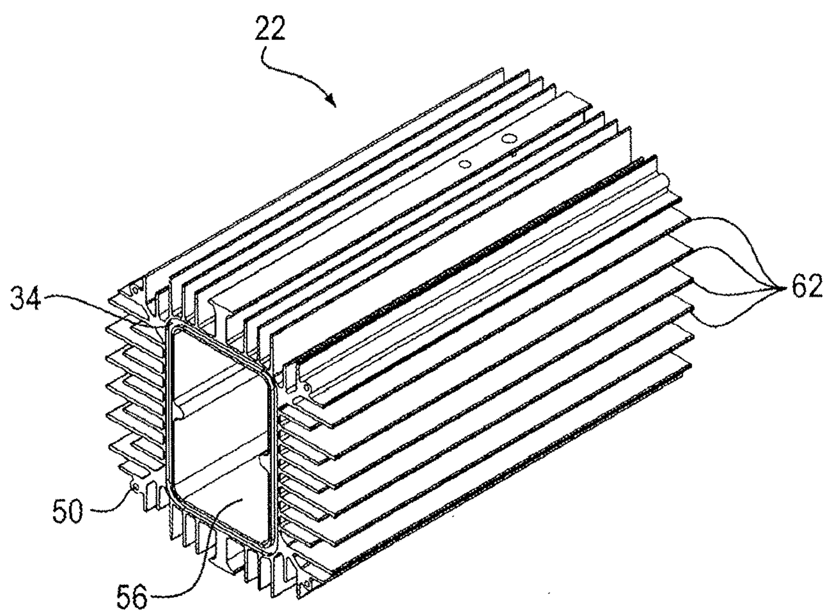


FIG. 10

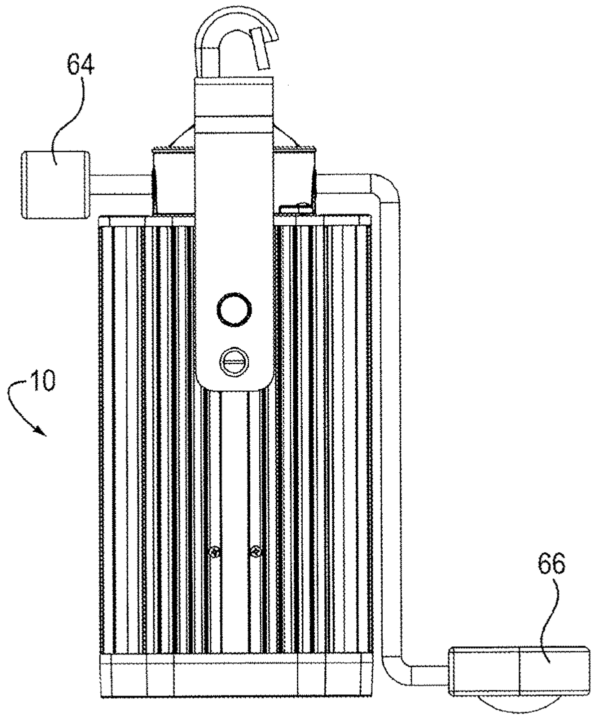


FIG. 11

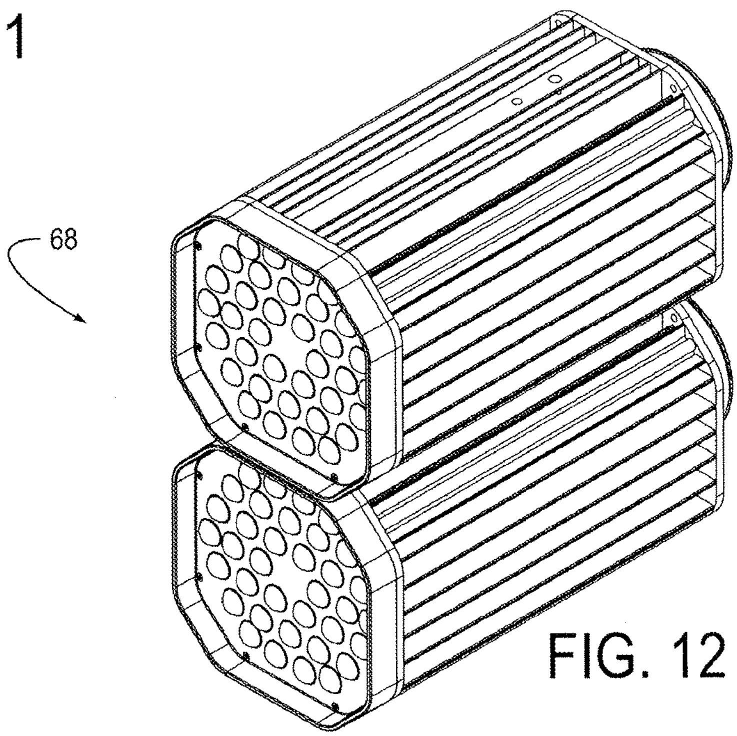


FIG. 12

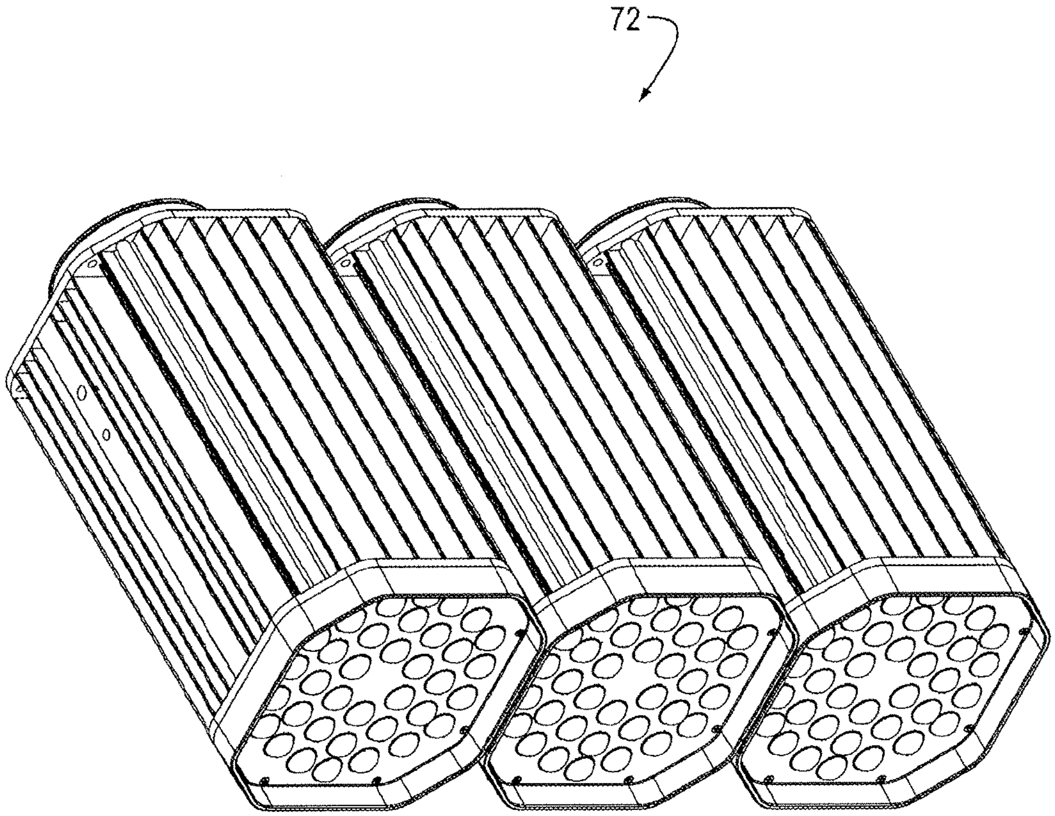
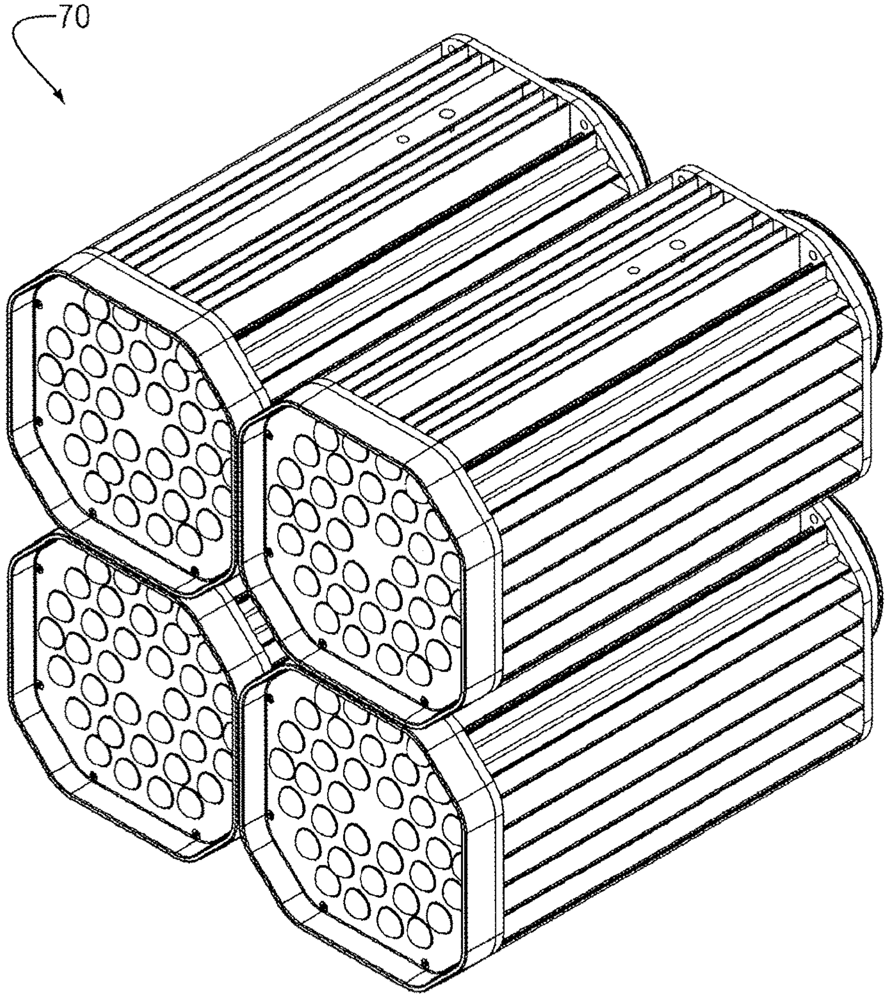


FIG. 13



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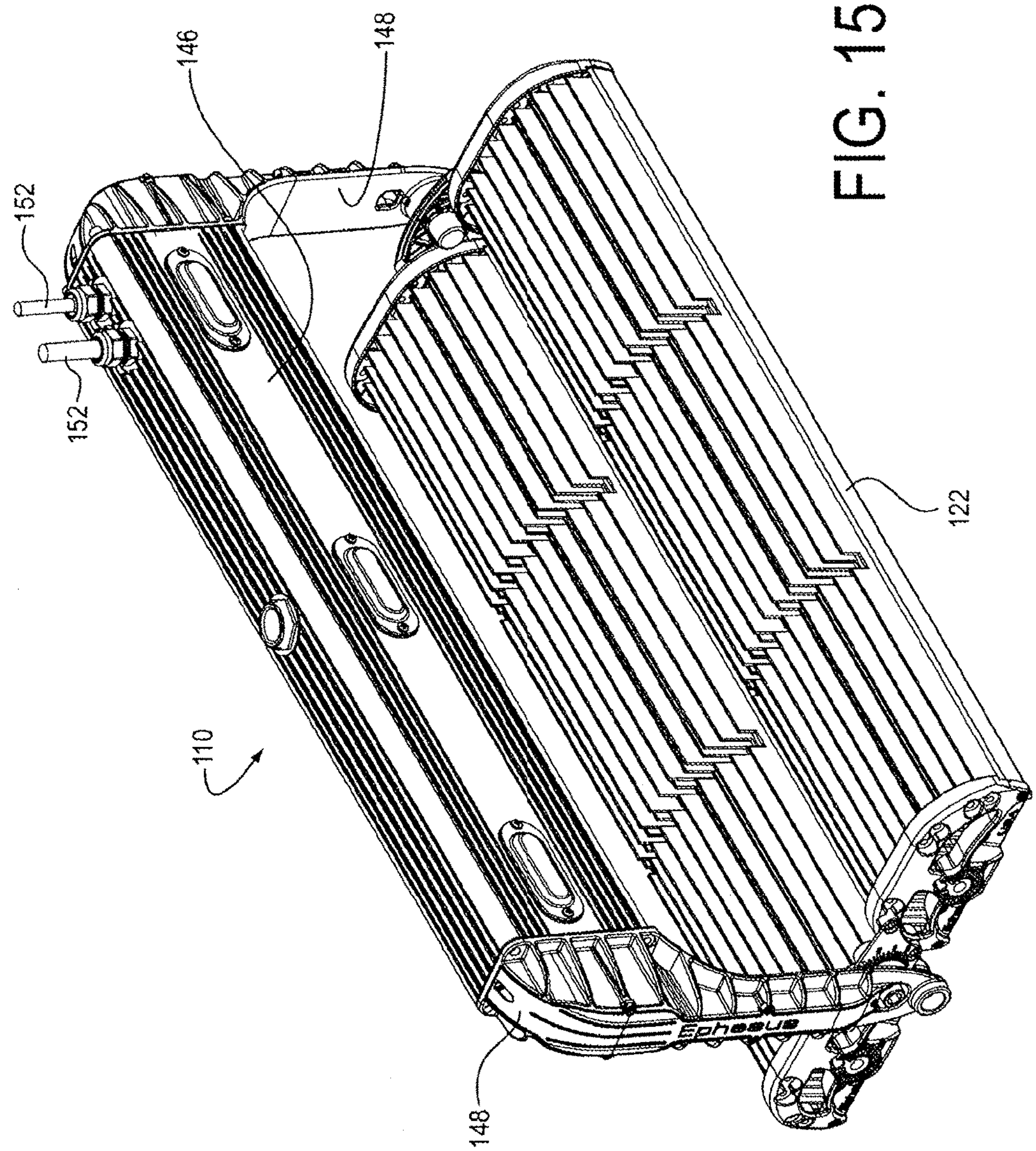


FIG. 15

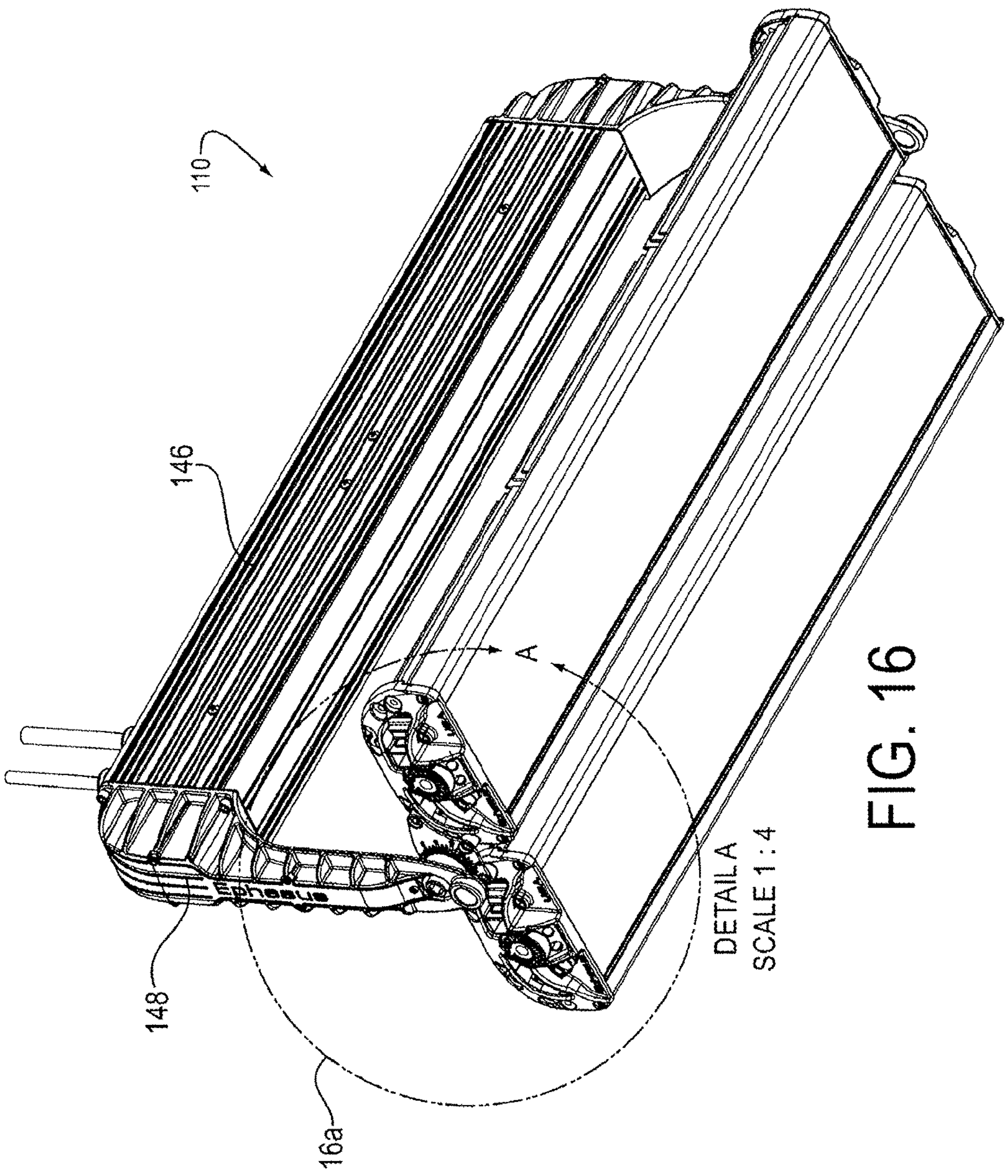


FIG. 16

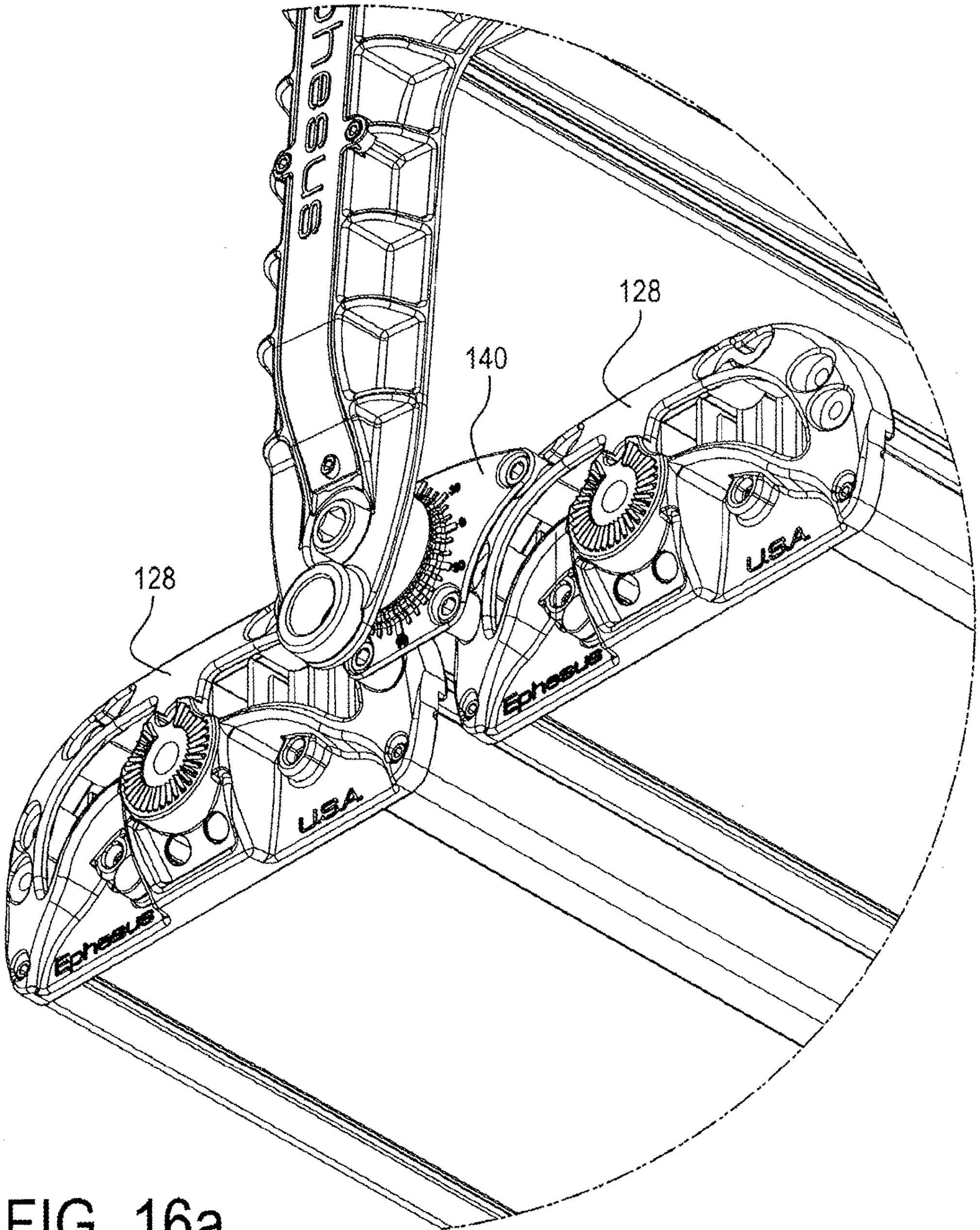
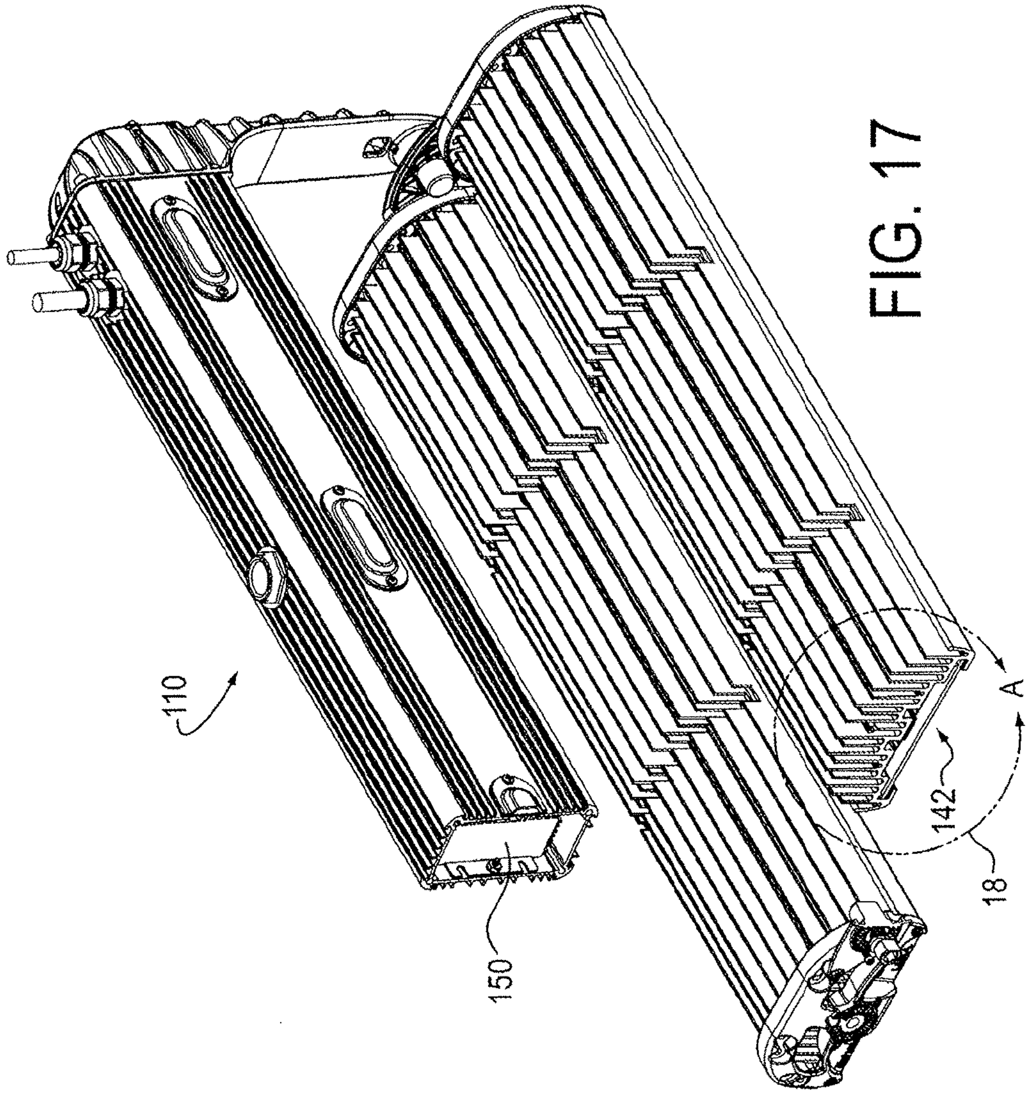


FIG. 16a



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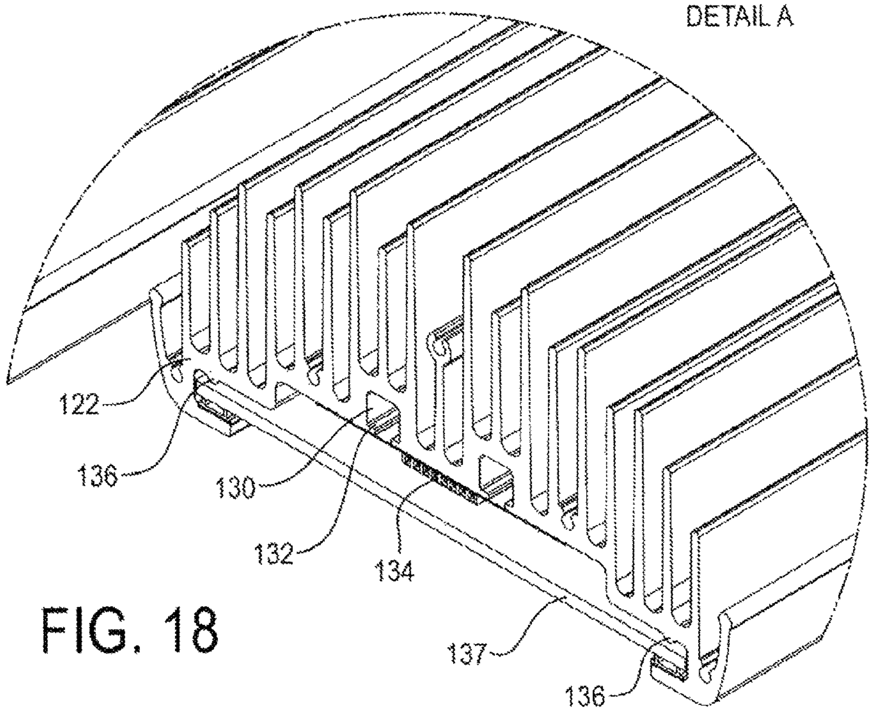
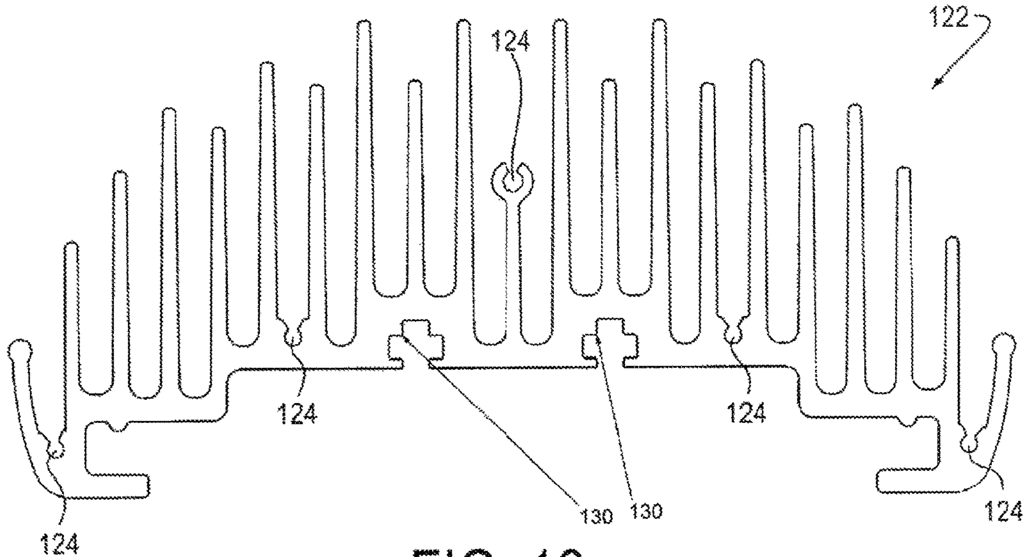

DETAIL A
122
136
130
132
134
137
136

FIG. 18


122
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124
124
124
124
130
130

FIG. 19

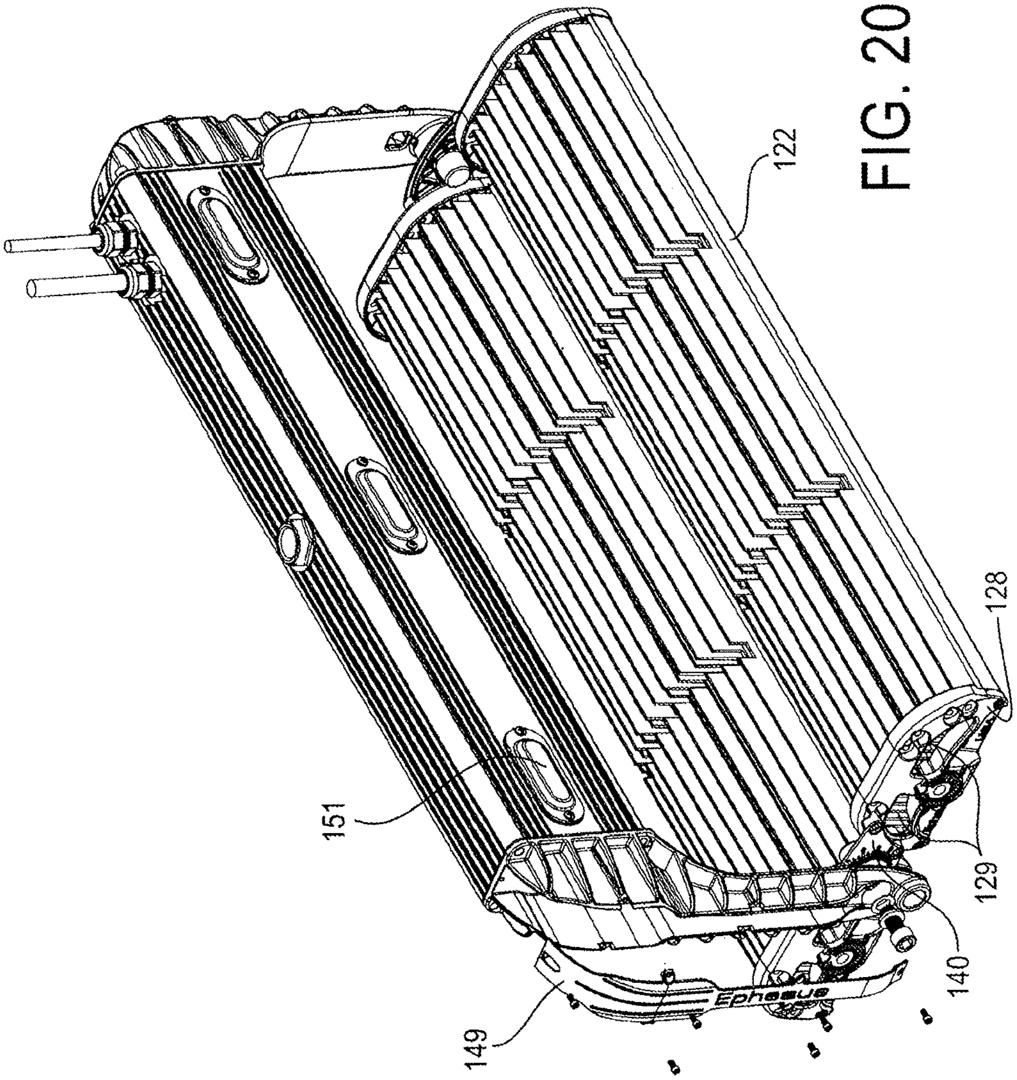


FIG. 20

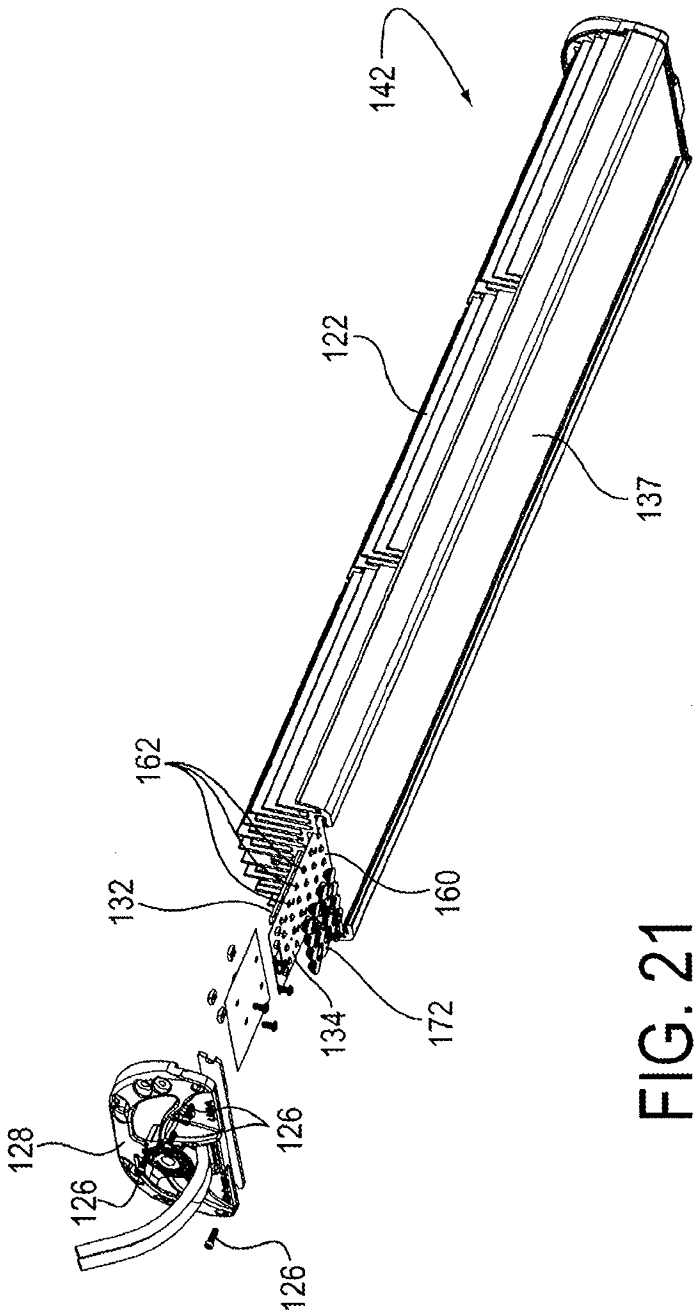


FIG. 21

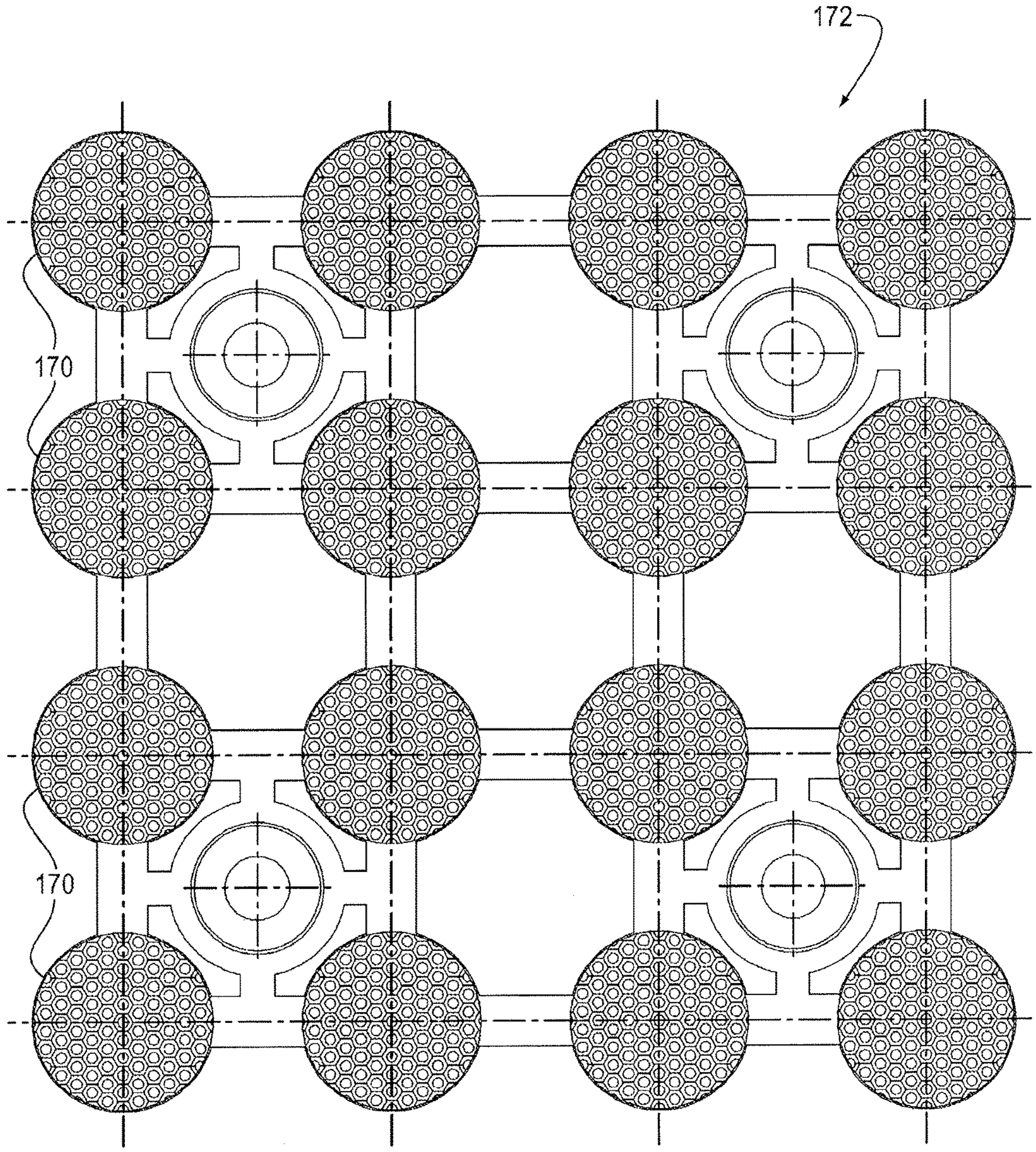


FIG. 22

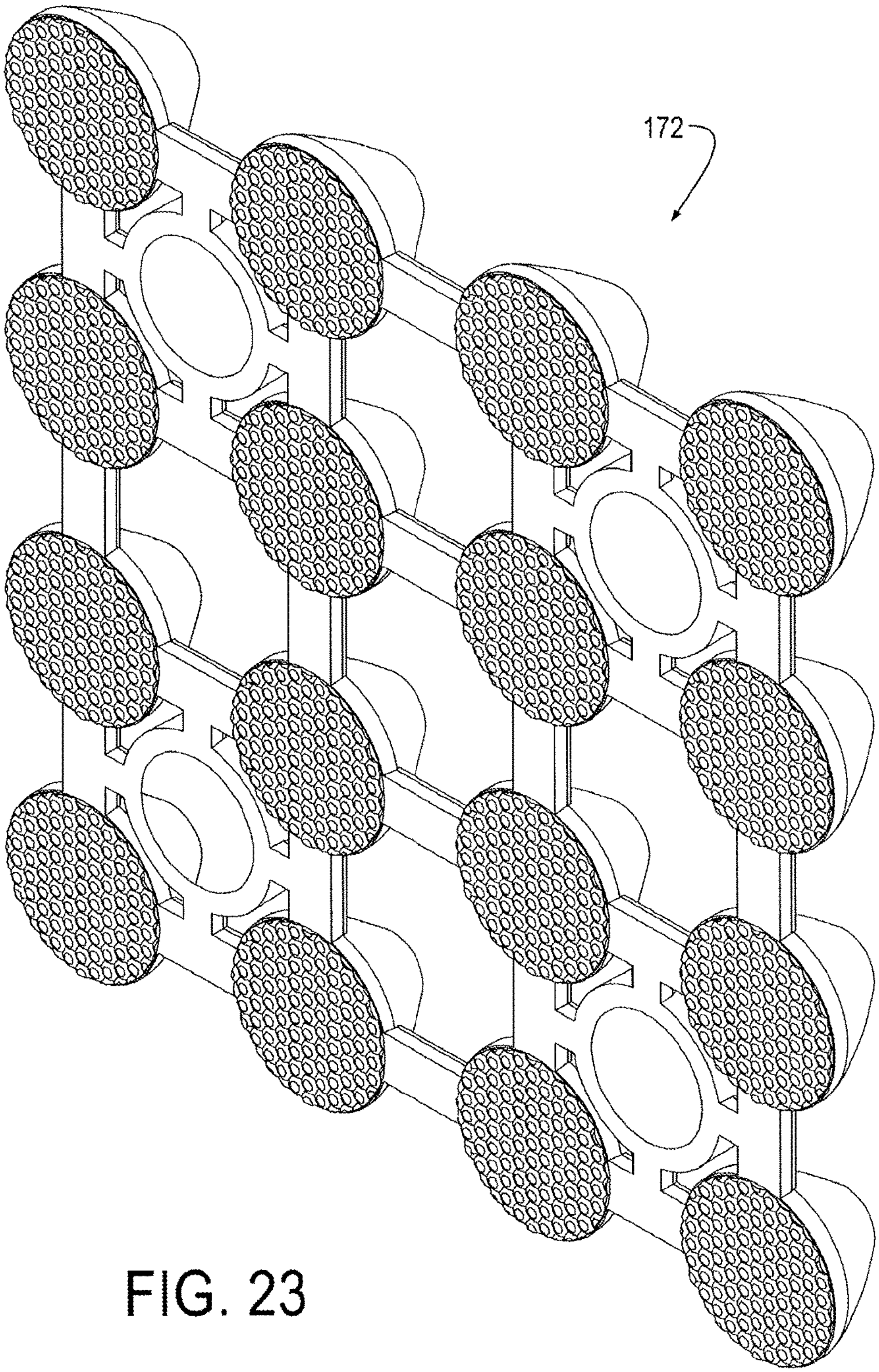


FIG. 23

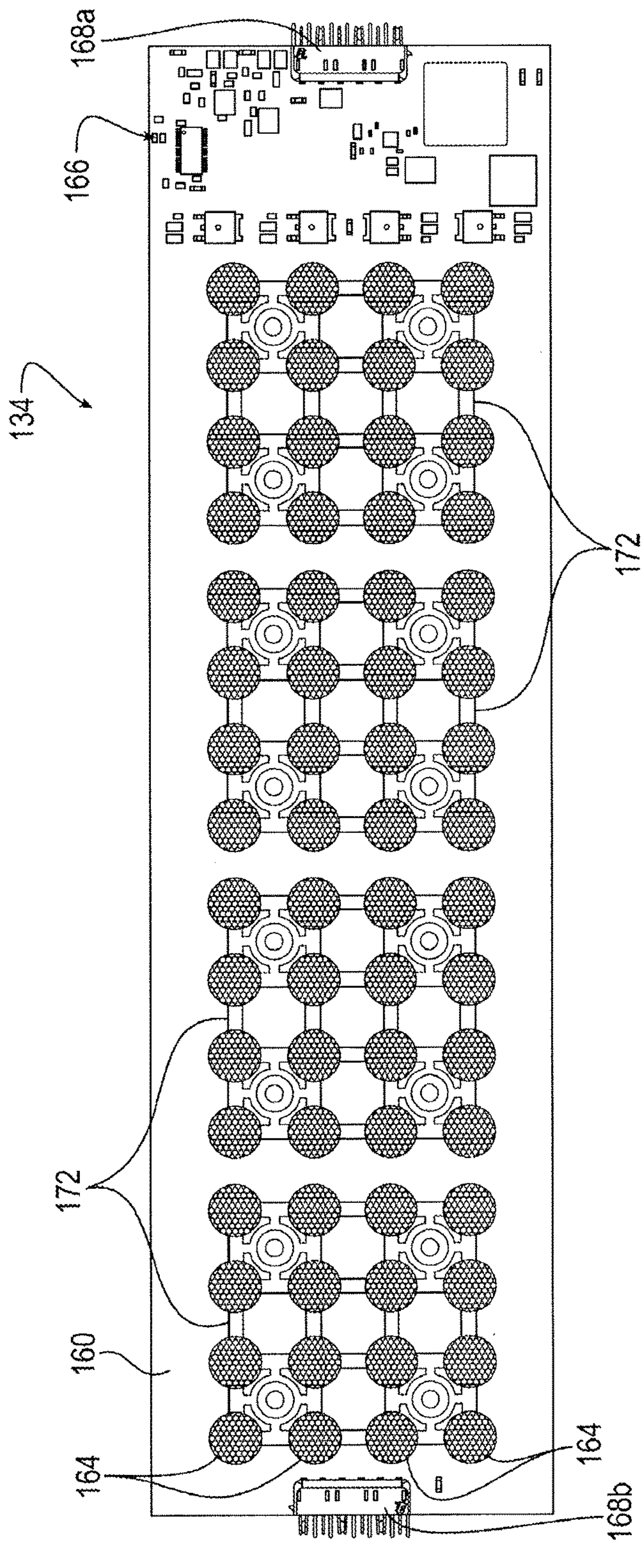


FIG. 24

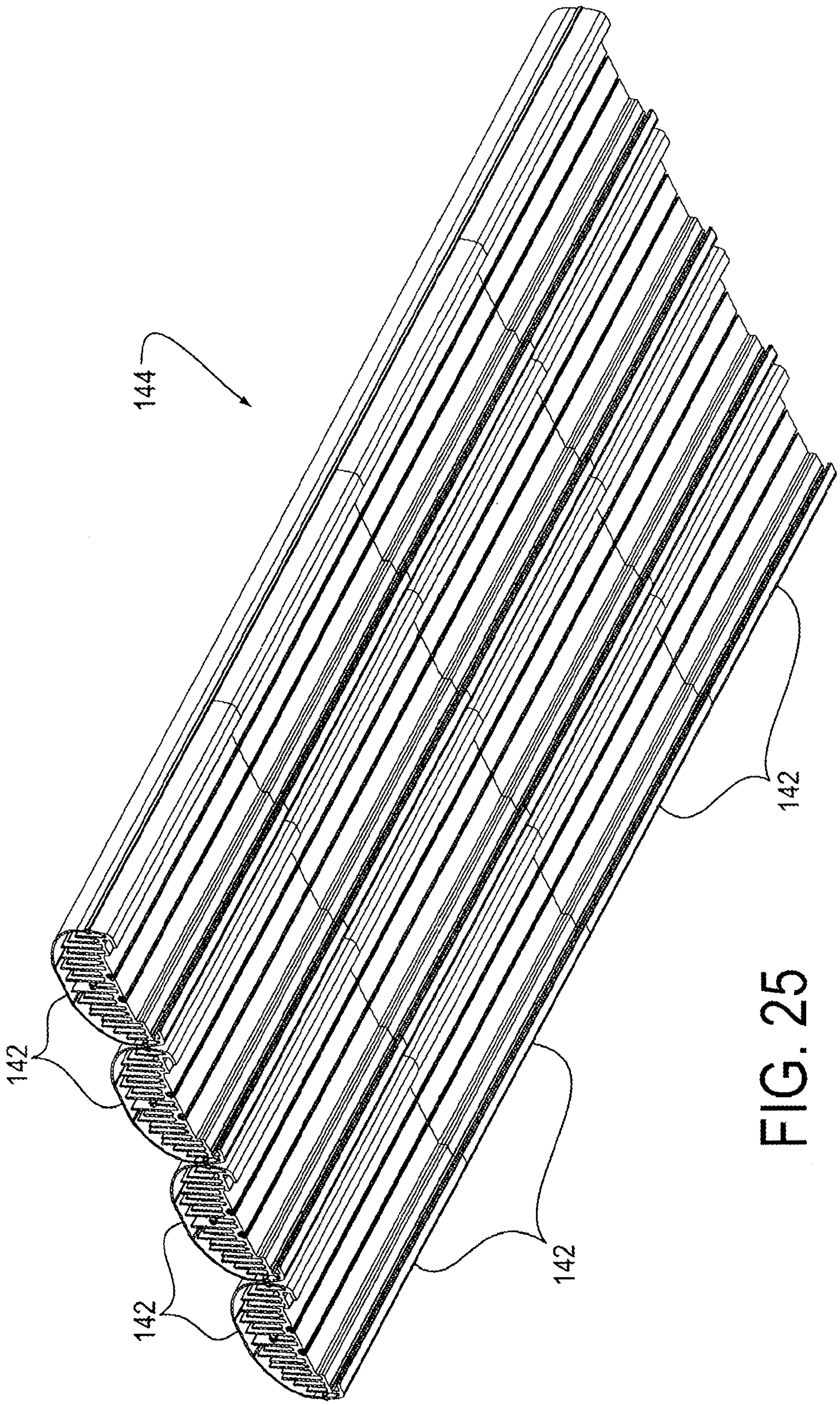


FIG. 25

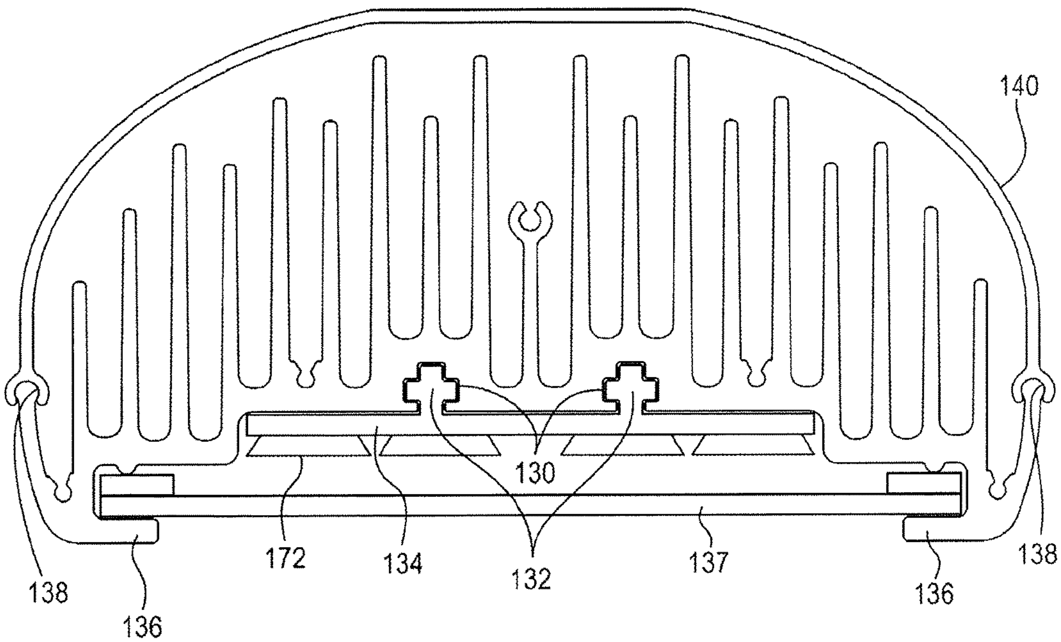


FIG. 26

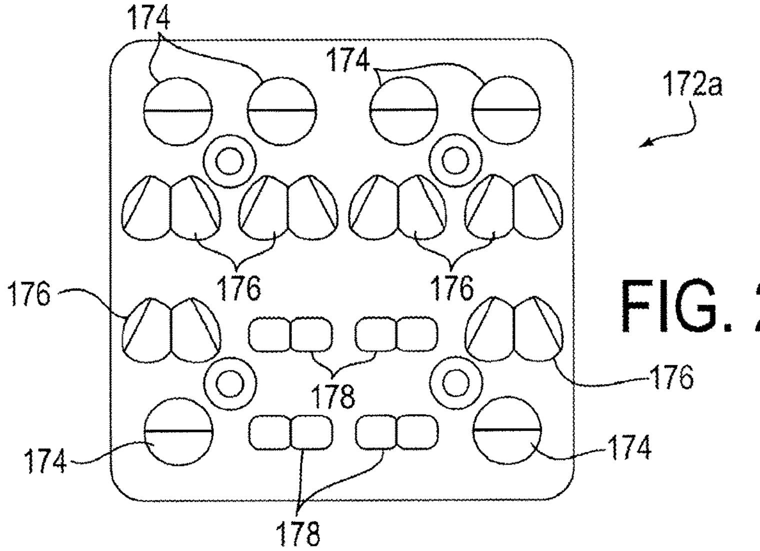


FIG. 27

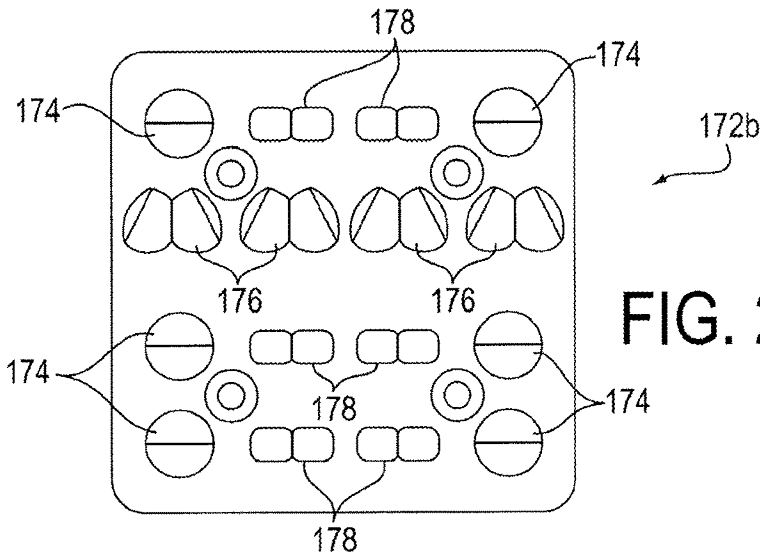


FIG. 28

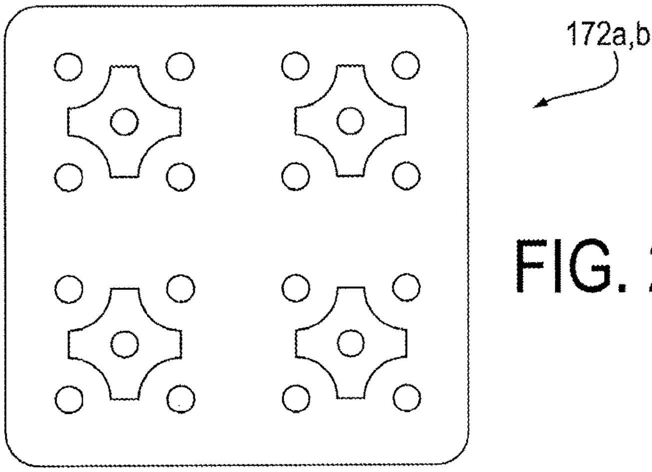
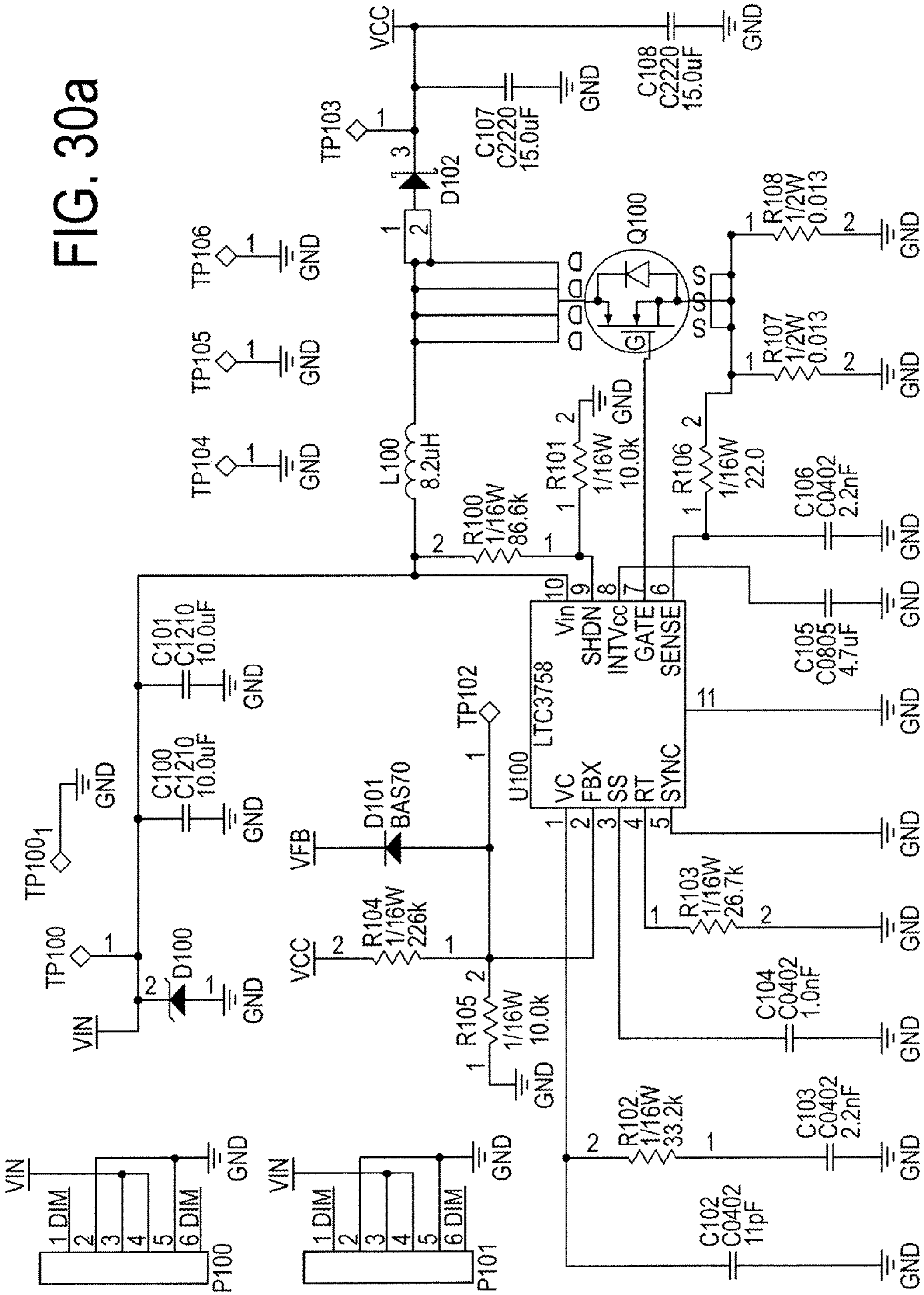


FIG. 29

FIG. 30a



VCC
GND
C108 C2220 15.0uF
C107 C2220 15.0uF
TP103
D102
Q100
R108 1/2W 0.013
R107 1/2W 0.013
TP104
TP105
TP106
L100 8.2uH
R100 1/16W 86.6k
R101 1/16W 10.0k
R106 1/16W 22.0
C106 C0402 2.2nF
C105 C0805 4.7uF
U100 LTC3758
Vin
SHDN
INTVcc
GATE
SENSE
VC
FBX
SS
RT
SYNC
C101 C1210 10.0uF
C100 C1210 10.0uF
TP100
TP102
D101 BAS70
VFB
D100
VIN
R104 1/16W 226k
R105 1/16W 10.0k
R103 1/16W 26.7k
C104 C0402 1.0nF
R102 1/16W 33.2k
C103 C0402 2.2nF
C102 C0402 11pF
P100
P101
DIM

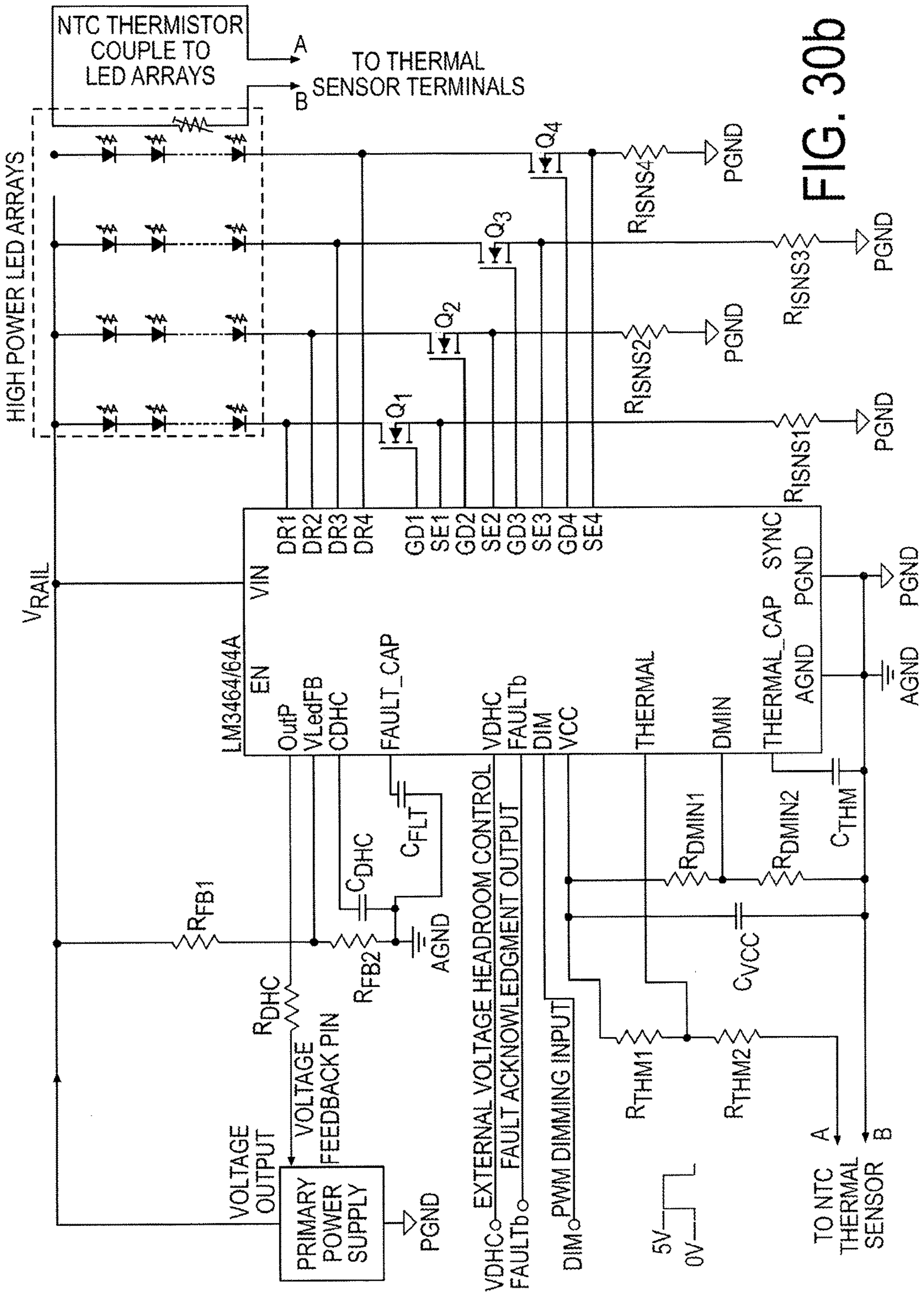
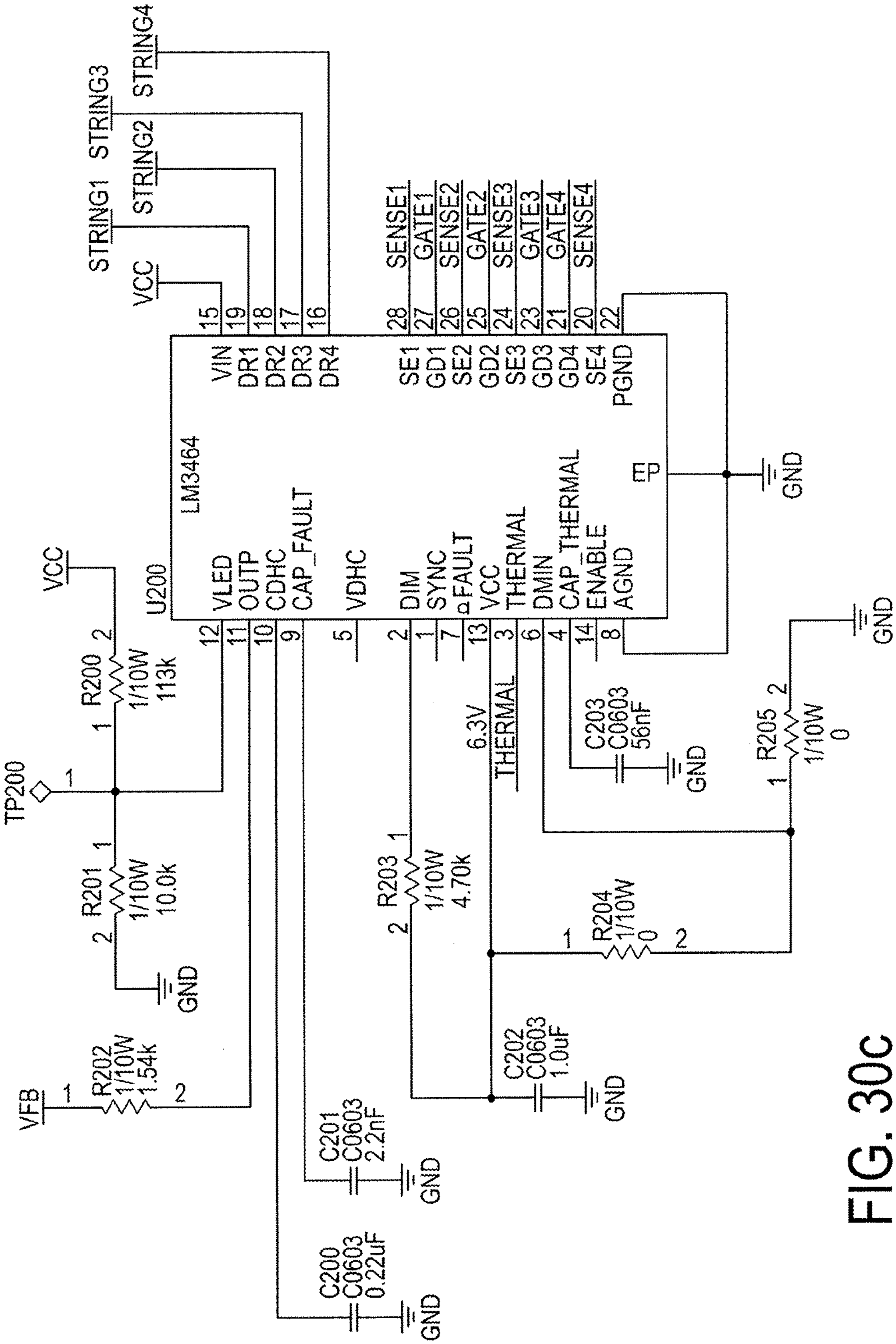

NTC THERMISTOR COUPLE TO LED ARRAYS
A
B
TO THERMAL SENSOR TERMINALS
HIGH POWER LED ARRAYS
Q4
Q3
Q2
Q1
RISNS4
RISNS3
RISNS2
RISNS1
PGND
VRAIL
LM3464/64A
VIN
EN
OutP
VLedFB
CDHC
FAULT_CAP
VDHC
FAULTb
DIM
VCC
THERMAL
DMIN
THERMAL_CAP
AGND
PGND
SYNC
DR1
DR2
DR3
DR4
GD1
SE1
GD2
SE2
GD3
SE3
GD4
SE4
RFB1
RFB2
AGND
CDHC
CFLT
RDHC
RDMIN1
RDMIN2
CTHM
CVCC
RTHM1
RTHM2
VOLTAGE OUTPUT
VOLTAGE FEEDBACK PIN
PRIMARY POWER SUPPLY
EXTERNAL VOLTAGE HEADROOM CONTROL
FAULT ACKNOWLEDGMENT OUTPUT
PWM DIMMING INPUT
VDHC
FAULTb
DIM
5V
0V
TO NTC THERMAL SENSOR

FIG. 30b



STRING4
STRING3
STRING2
STRING1
VCC
SENSE1
GATE1
SENSE2
GATE2
SENSE3
GATE3
GATE4
SENSE4
LM3464
U200
VIN
DR1
DR2
DR3
DR4
SE1
GD1
SE2
GD2
SE3
GD3
GD4
SE4
PGND
EP
GND
VLED
OUTP
CDHC
CAP_FAULT
VDHC
DIM
SYNC
FAULT
VCC
THERMAL
DMIN
CAP_THERMAL
ENABLE
AGND
R200
1/10W
113k
TP200
R201
1/10W
10.0k
R202
1/10W
1.54k
VFB
C201
C0603
2.2nF
C200
C0603
0.22uF
R203
1/10W
4.70k
6.3V
THERMAL
C202
C0603
1.0uF
R204
1/10W
0
C203
C0603
56nF
R205
1/10W
0

FIG. 30c

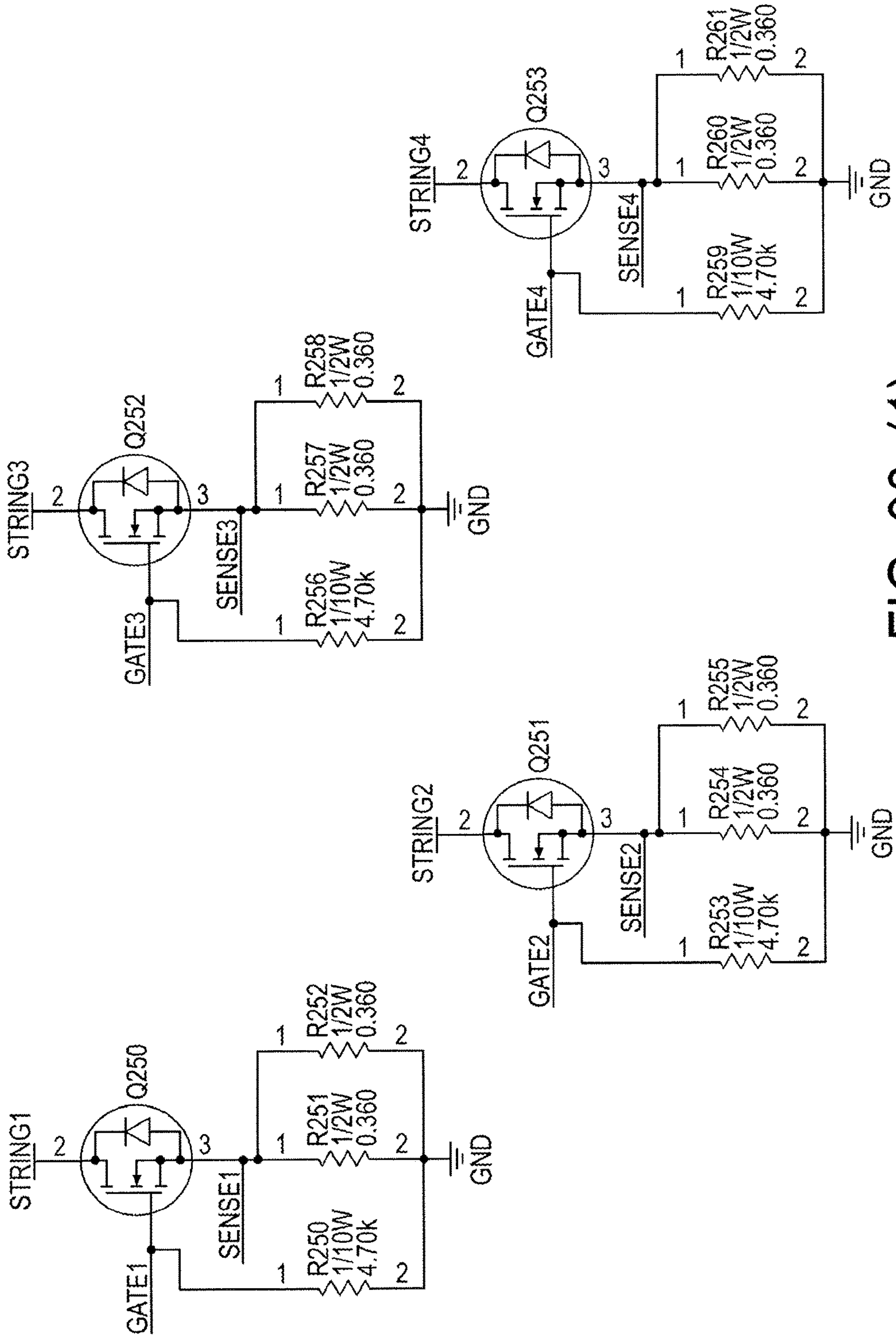

STRING4
Q253
GATE4
SENSE4
R259 1/10W 4.70k
R260 1/2W 0.360
R261 1/2W 0.360
GND
STRING3
Q252
GATE3
SENSE3
R256 1/10W 4.70k
R257 1/2W 0.360
R258 1/2W 0.360
GND
STRING2
Q251
GATE2
SENSE2
R253 1/10W 4.70k
R254 1/2W 0.360
R255 1/2W 0.360
GND
STRING1
Q250
GATE1
SENSE1
R250 1/10W 4.70k
R251 1/2W 0.360
R252 1/2W 0.360
GND

FIG. 30c(1)

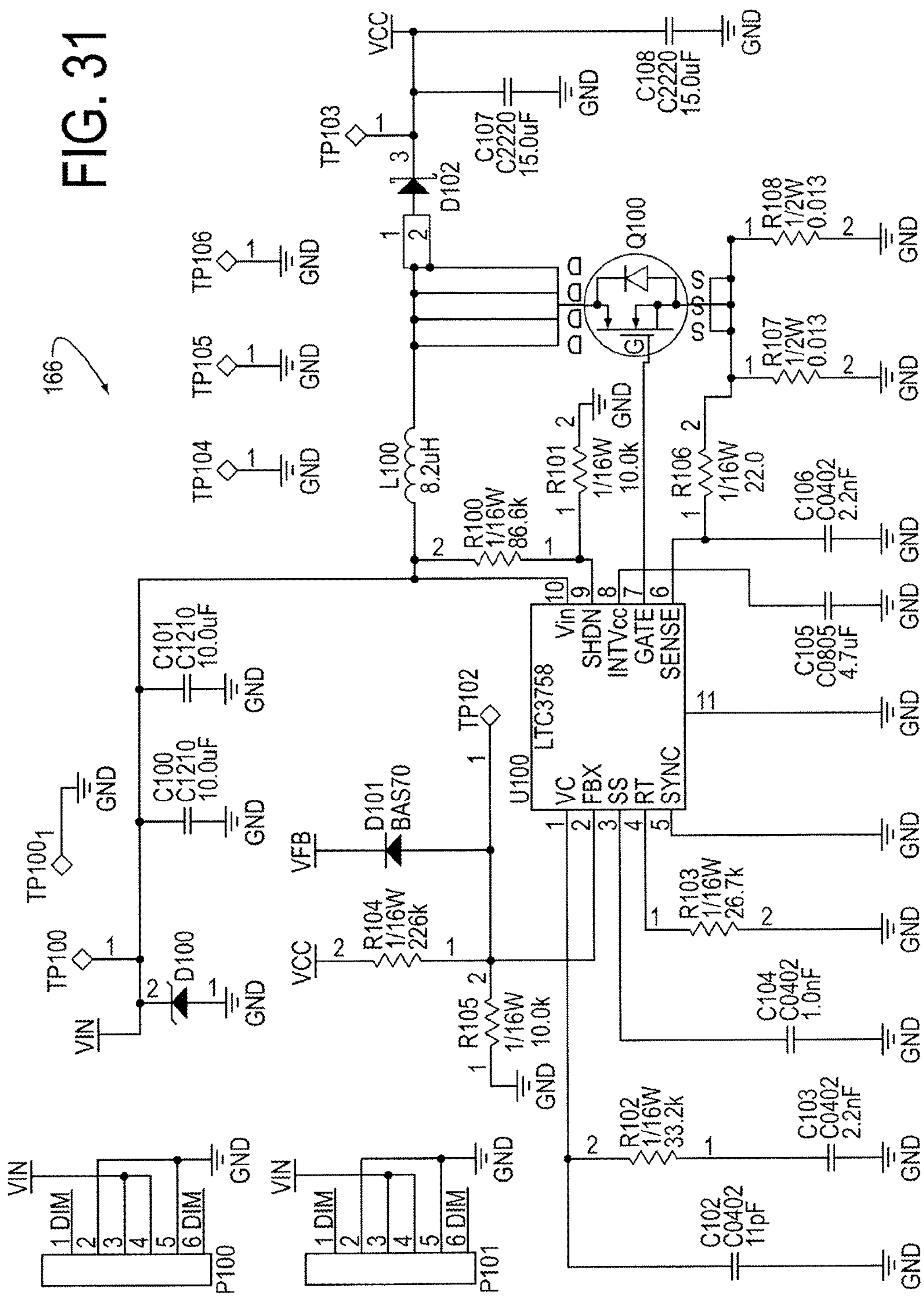

166
VCC
GND
TP103
D102
C107
C2220
15.0uF
C108
C2220
15.0uF
TP104
TP105
TP106
L100
8.2uH
Q100
R100
1/16W
86.6k
R101
1/16W
10.0k
R106
1/16W
22.0
R107
1/2W
0.013
R108
1/2W
0.013
C106
C0402
2.2nF
C105
C0805
4.7uF
U100
LTC3758
Vin
SHDN
INTVcc
GATE
SENSE
VC
FBX
SS
RT
SYNC
C101
C1210
10.0uF
C100
C1210
10.0uF
TP100
TP102
D100
D101
BAS70
VFB
VIN
R104
1/16W
226k
R105
1/16W
10.0k
R103
1/16W
26.7k
C104
C0402
1.0nF
R102
1/16W
33.2k
C103
C0402
2.2nF
C102
C0402
11pF
P100
P101
1 DIM
6 DIM

FIG. 31

HIGH INTENSITY LIGHT-EMITTING DIODE LUMINAIRE ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of: (i) U.S. provisional patent application Ser. No. 61/570,072, entitled "High Intensity Light-Emitting Diode (LED) Luminaire and Methods for Making Same," filed Dec. 13, 2011, (ii) Ser. No. 61/712,226, entitled "High Intensity Light-Emitting Diode Luminaire Assembly," filed Oct. 10, 2012, and (iii) International patent application Serial No. PCT/US2012/069442, filed Dec. 13, 2012, each of which is incorporated herein by reference in its entirety

1. TECHNICAL FIELD

The present invention relates to high intensity light-emitting diode (LED) array technology. The invention further relates high intensity LED luminaires and high intensity LED luminaire (HILL) assemblies and methods for making them.

2. BACKGROUND OF THE INVENTION

High intensity light-emitting diode (LED) array technology is currently used to provide lighting in a wide range of applications in which the user needs high intensity illumination.

One drawback of existing high intensity LED luminaire (HILL) assemblies (also known as high intensity LED light fixtures or high intensity LED light fittings) is poor thermal management, which drastically reduces product lifespan. Extended operation of LEDs at temperatures significantly above ambient is not possible with existing HILL designs, yet such assemblies throw off large amounts of heat which are not adequately dispersed.

Another drawback of existing luminaire or HILL assemblies is their "throw-away" design. Lack of in-field serviceability leads to disposal of the entire luminaire assembly rather than replacing its electronics. This wastes resources, since many components that are still serviceable. Furthermore, existing HILLs lack balanced current control and can be prone to "thermal runaway," which in turn can cause premature failure of the luminaire and shorten its lifespan.

Another drawback of existing HILLs is off-angle glare: when an overhead luminaire is operating, users at ground level see spikes of light intensity emitted by the luminaire, rather than consistent and even illumination over the entire illuminated field.

Citation or identification of any reference in Section 2, or in any other section of this application, shall not be considered an admission that such reference is available as prior art to the present invention.

3. SUMMARY OF THE INVENTION

A high intensity LED luminaire (HILL) assembly is provided comprising:

- a LED module comprising:
  - a LED array comprising a plurality of LEDs positioned in the LED array, and
  - a circuit board (also referred to herein as a circuit card),
- a secondary lens element comprising a plurality of lenses, wherein the plurality of lenses is positioned adjacent to the plurality of LEDs;

- a heatsink; and
- driver circuitry for driving the LEDs in communication (or operatively connected) with the circuit board.

In one embodiment, the heatsink is a heatsink housing.

In one embodiment, the LED module comprises the secondary lens element.

In another embodiment, the HILL assembly comprises a plurality of LED modules comprising secondary lens elements.

In another embodiment, the plurality of lenses comprises at least two different types of LED lenses.

In another embodiment, the circuit board employs thermal via technology.

In another embodiment, the HILL assembly comprises a lens for attenuating a light source as seen from an angle and for reducing off-angle glare.

In another embodiment, the LED module is removable and/or replaceable from the heatsink or heatsink housing.

In another embodiment, the plurality of LEDs is mounted on the circuit board.

In another embodiment, the plurality of LEDs is arranged in a circular or rectilinear array on the circuit board.

In another embodiment, the driver circuitry is disposed on its own driver circuitry card.

In another embodiment, the driver circuitry is disposed on the circuit board.

In another embodiment, at least one lens of the plurality of lenses is a concavo-convex lens (CCL).

In another embodiment, the plurality of lenses is formed as (or forms or is configured to form) at least one lens matrix.

In another embodiment, the at least one lens matrix can be screwed down on top of its respective LEDs to vary size and shape of a field illuminated by each LED.

In another embodiment, the heatsink or heatsink housing is formed as a single unit.

In another embodiment, the heatsink or heatsink housing comprises a plurality of fins.

In another embodiment, the heatsink or heatsink housing is formed as a single unit and comprises a plurality of fins.

In another embodiment, the circuit board is disposed transversely of the fins at an end of the heatsink or heatsink housing.

In another embodiment, the circuit board is disposed parallel to the fins.

In another embodiment, the HILL assembly comprises a plurality of LED modules.

In another embodiment, the HILL assembly comprises a sensor for sensing and/or providing data relating to the HILL assembly or to environmental parameters.

In another embodiment, the HILL assembly comprises a sealing lens.

In another embodiment, the sealing lens comprises a frosted lip for attenuating a light source as seen from an angle.

In another embodiment, the HILL assembly comprises a power supply attached to the driver circuitry.

In another embodiment, the LEDs are dimmable by pulse width modulation (PWM).

In another embodiment, the LED module has an operational temperature range from about −40° C. to about +80° C.

In another embodiment, the heatsink or heatsink housing is provided with at least one mating feature (e.g., T-slot) for enabling a modular connection with a second LED module and for connecting the circuit card to the heat sink, and the

LED module is provided with at least one corresponding mating feature (e.g., T-mating feature).

In another embodiment, the circuit board comprises via technology, wherein the via technology comprises a conductive backing selected from the group consisting of copper and graphene.

In another embodiment, the HILL assembly comprises a DC power supply. In another embodiment, the DC power supply comprises an AC-DC converter for converting incoming AC voltage between 100v and 480v AC to 24v DC operating voltage.

In another embodiment, the driver circuitry comprises feedback circuitry for constantly balancing power input to each of a plurality of LED strings.

In another embodiment, the driver circuitry allows the plurality of LEDs to be continuously operated at operating temperatures up to 80° C. while providing an output of 100 lumens/watt from each LED.

In another embodiment, the heatsink or heatsink housing is a linear, one-piece, finned, metal heatsink.

In another embodiment, the HILL assembly comprises at least one joiner.

In another embodiment, the HILL assembly comprises at least one bracket.

A bracket for a HILL assembly is also provided. In one embodiment, the bracket comprises an extruded aluminum bracket body comprising at least one arm, wherein the bracket body is formed to produce a cavity and wherein the cavity is configured to receive a power supply; and a bracket arm cover for each arm of the bracket body, wherein the bracket body is configured for multiple angular mounting options (wall, ceiling, pendant, etc.).

A method for maintaining a constant LED color temperature and/or a color rendering index in a lighting assembly (e.g., a HILL assembly) is also provided. The method can comprise the steps of using constant drive current, thereby decreasing photon emissions; and varying pulse width modulation (PWM).

4. BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described herein with reference to the accompanying drawings, in which similar reference characters denote similar elements throughout the several views. It is to be understood that in some instances, various aspects of the invention may be shown exaggerated, enlarged, exploded, or incomplete to facilitate an understanding of the invention.

FIG. **1** is a perspective drawing of a first embodiment of a HILL assembly in accordance with the present invention.

FIG. **2** is an exploded perspective view of the embodiment shown in FIG. **1**.

FIG. **3** is a plan view of a lens element comprising a plurality of concavo-convex lenses (CCLs) for use in the first embodiment for flood lighting.

FIG. **4** is a cross-sectional view taken along line **4-4** in FIG. **3**.

FIG. **5** is a plan view of a LED array for use in the first embodiment.

FIG. **6** is a side view of the LED array shown in FIG. **5**.

FIG. **7** is a perspective view of an outer frosted dome lens for use in a low bay application of the first embodiment.

FIG. **8** an exploded perspective view and an assembled view of a LED module (also referred to herein as LED replacement module) in accordance with the present invention comprising a LED array, thermal gaskets, interface plate, a current balancing controller FR4 circuit card, and a power supply connector.

FIGS. **9** and **10** respectively are an end view and a perspective view of a heatsink housing as shown in FIGS. **1** and **2**.

FIG. **11** is a side view of the HILL assembly shown in FIGS. **1** and **2** further comprising an ambient light sensor and an occupancy sensor.

FIGS. **12** through **14** are perspective views showing various mounting configurations that can be achieved with the first HILL assembly embodiment shown in FIG. **1**.

FIGS. **15** and **16** are perspective views from above and below, respectively, of a second embodiment of a HILL assembly in accordance with the present invention.

FIG. **16*a*** is an enlarged view of the portion of FIG. **16** shown in circle **16*a*** showing the joiner with mating edges.

FIG. **17** is a view like that shown in FIG. **15** showing a portion of one bank of LED lamp assembly cutaway.

FIG. **18** is an enlarged view of the portion of FIG. **17** shown in circle **18**.

FIG. **19** is an end view of a finned heatsink.

FIG. **20** is a first exploded perspective view from above of the second embodiment shown in FIG. **15**.

FIG. **21** is a second exploded perspective view from below of the second embodiment shown in FIG. **15**.

FIG. **22** is a plan view of an idealized 16-lens module in accordance with the present invention.

FIG. **23** is a perspective view of the idealized lens module shown in FIG. **22**.

FIG. **24** is a plan view of a modular circuit board assembly in accordance with the present invention.

FIG. **25** is an isometric view of an exemplary multiple-module assembly of HILLs in accordance with the second embodiment shown in FIG. **21**.

FIG. **26** is an end view of an exemplary single-module HILL in accordance with the second embodiment shown in FIG. **21**.

FIG. **27** is a plan view of a first exemplary embodiment of a 16-lens modular subassembly in accordance with the present invention.

FIG. **28** is a plan view of a second exemplary embodiment of a 16-lens modular subassembly in accordance with the present invention.

FIG. **29** is a plan view of the reverse side of either of the first and second embodiments shown in FIGS. **27** and **28**.

FIGS. **30*a***, **30*b***, **30*c***, **30*c*(1)**, and FIG. **31** are electrical drawings of LED driver circuitry in accordance with the present invention.

5. DETAILED DESCRIPTION OF THE INVENTION

A high intensity LED luminaire (HILL) assembly (also known in the art as a high intensity LED light fixture, high intensity LED light fitting or LED luminaire) is provided. The HILL assembly can be used indoors or outdoors, and in wet, damp or dry environments. In various embodiments, the HILL can be powered by a universal AC (90-480 VAC, 47-440 Hz) or a DC (12-480 VDC) electrical supply. The operational temperature range for the HILL is from about −40° C. to about +80° C. In a preferred embodiment, the HILL assembly comprises a heatsink, referred to herein as a "heatsink housing," that serves the dual purpose of functioning as the housing for the HILL assembly and as the heatsink for the HILL assembly.

A HILL assembly in accordance with a first embodiment of the present invention can comprise a LED module that is replaceable (or exchangeable or interchangeable) having a plurality of LEDs disposed in a LED array; an array of concavo-convex lenses (CCLs, also known in the art as "concave meniscus" lenses) disposed adjacent to the LED array; a thermal insulator; a heatsink housing; a power supply and associated circuitry; and a circuit board for controlling the LED array by thermal via technology. The LEDs are mounted directly on the circuit board. A first embodiment HILL assembly is well adapted for use, for example, as a floodlight, spotlight, worklight, or hand-held flashlight.

In a second embodiment, the LEDs are arranged in a circular or rectilinear modular array. Modules in the modular array may be ganged together into larger units for use in, for example, overhead room lighting, desk lighting, street lighting, or stadium lighting. Lenses can be adjustable to vary the size and shape of the field illuminated by each LED. In certain embodiment, the power supply driving circuitry can be positioned or mounted directly on the circuit board.

In various embodiments, the HILL assembly can be used for lighting indoor or outdoor areas or for flood lighting. It can be used in high bay or low bay applications. It will be apparent to the skilled artisan that the HILL assembly has many uses for illuminating commercial or industrial settings, but can also be used in residential settings. The commercial or industrial settings in which the HILL assembly can be used can include, but are not limited to, offices, manufacturing facilities, warehouses, parking garages, ball parks, stadiums, and storage areas.

For clarity of disclosure, and not by way of limitation, the detailed description of the invention is divided into the subsections set forth below.

5.1. High Intensity LED Luminaire (HILL) Assembly—First Embodiment

Referring now to FIGS. **1-16**, a first embodiment **10** of a HILL assembly in accordance with the present invention comprises at least a secondary lens element **12** comprising a plurality of CCLs **14**; a LED module **16**, comprising a plurality of LEDs **18** equal in number to the number of CCLs **14**, positioned in a first LED array **20**; a heatsink (also referred to herein as a heatsink housing) **22**; and a power supply **24** disposed within heatsink housing **22**. Embodiment **10** further comprises a first O-ring **28**; first and second thermal gaskets **30**; an interface plate **32**; a second O-ring **34** for sealing heatsink housing **22** at the front end; a third O-ring **36** for sealing heatsink housing **22** at the rear end; a back plate **38**; a junction box **40**; and sealing gaskets **42**.

Lens Element

HILL assembly **10** comprises a single secondary lens element **12** (FIGS. **2-3**) with one or more CCLs **14** integrated into the lens element. Lens element **12** is also referred to herein as a secondary lens, because the primary lens is a part of the actual LED chip itself. Lens element **12** is preferably made of injection molded plastic, and more preferably, a high temperature acrylic. Other materials, such as borosilicate glass or an optical grade polyycarbonate, can also be used. In first embodiment **10**, lens element **12** can comprise a plurality of CCLs **14** (in this embodiment, **36** in number, see FIGS. **1-3**) integrated into a singular lens element. As shown in FIG. **4**, the concave lens surface **25** of each CCL **14**, in combination with the convex lens surface **26** of the CCL, creates wide dispersion optics. After assembly of embodiment **10**, each LED **18** is positioned within the concavity of one of the concave surfaces **24** when the lens element **12** is positioned on or attached to the LED array **20** (FIGS. **4-6**). In some embodiments, the outer edges **19** of lens element **12** (FIGS. **3-4**) can be frosted to reduce off-angle glare.

FIG. **7** shows a perspective view of a different embodiment of a secondary lens element **12**A for use in a low bay application. FIG. **7** contains one or more CCLs **14** integrated into the lens element. Secondary lens element **12**A comprises a hexagonal lens **14**A that is used to make a more uniform distribution of light on the ground for individual LEDs in LED array **20**.

LED Array

HILL assembly **10** comprises a LED array **20** comprising a plurality of LEDs **18** positioned in the array (see FIGS. **2**, **5** and **6**). Any suitable LED or plurality of LEDs known in the art can be used in the LED array **20**. Each of the LED elements **18** comprises a primary lens.

HILL assembly **10** also comprises one or more securing screws **44** (FIGS. **5** and **8**) or any other suitable securing fastener, adhesive, clamp, spring pin, or tensioning device that secures the LED array **20** in place. In first embodiment **10**, a plurality of screws **44** (a plurality of 10 screws in the embodiment illustrated in FIGS. **5** and **8**) are used to secure the various components of the HILL assembly, including the LED array **20**, to interface plate **32** (see FIGS. **2** and **8**). In a preferred embodiment, the LED array **20** is a component of a LED module **16** ((also referred to herein as a LED "replaceable" or "replacement" module; FIGS. **2** and **8**), which can be removed in the field (i.e., where it is installed) through removal of the securing screws **44**. This enables the LED module **16** comprising the LED array **20** to be exchanged, interchanged or replaced as desired by the user.

The LED array **20** comprises a circuit board or card **46** (FIG. **5**) for controlling the LED array. Preferably, the circuit card **46** is a FR4 circuit board, which is a low-cost fiberglass reinforced epoxy laminate known in the art that is flame retardant. Although metal clad circuit cards known in the art, such as metal core printed circuit boards (MCPCB) can also be used, their use is less preferred, since they have a much greater cost than FR4 circuit boards. In a preferred embodiment, circuit board **46** employs FR4 with thermal via technology to provide a low cost circuit board that performs thermally equivalent or better than a metal clad circuit board. Incorporating thermal vias into board design is well known in the art, and mitigates thermal issues by lowering the thermal resistance of the circuit card itself, (see, e.g., Cree, Inc. (2010), Optimizing PCB Thermal Performance for Cree® XLamp® LEDs, Technical Article CLD-AP37 REV 1, Cree, Inc., 4600 Silicon Drive, Durham, N.C. 27703, available at http://www.cree.com/products/pdf/XLamp_PCB_Thermal.pdf (last visited Dec. 13, 2011); IPC 7093: Design and Assembly Process Implementation for Bottom Termination SMT Components ISBN 1-580986-90-0, available for purchase at http://www.ipc.org, Table of Contents available free at http://www.ipc.org/TOC/IPC-7093.pdf (last visited Dec. 13, 2011)).

The LED array **20** preferably comprises parallel strings of LEDs **18**, which arrangement confers several advantages. First, this allows for graceful degradation as the array ages. For example, in an embodiment with four parallel strings of LEDs, two of the four strings can fail and the light will still provide the rated lumen output. Second, the LED array does not experience hot spots that reduce LED lifespan. By balancing the current through each string to be within 1% of one another, the LED array runs at a uniform temperature. Hot spots form on a LED array when designs use parallel

strings without current balancing. As the array powers up, most of the current travels down the string with the lowest voltage potential. Since not all LEDs are created equal, this will happen. When a single string uses more current than the other strings, those LEDs heat up faster than the others. As the string heats up, the LEDs' voltage potential drops, which in turn causes the LEDs to consume more current from the cooler strings. This effect is known in the art as "thermal runaway" and causes LED arrays to fail prematurely.

In contrast to existing HILL assemblies that have LED arrays either permanently bonded to the heatsink housing **22** or connected through use of a thermal paste, a HILL assembly **10** in accordance with the present invention comprises a LED module **18** comprising a LED array **20** that is a removable and/or exchangeable component and not a permanently installed component of the HILL assembly. The LED array **20** is preferably a component of a LED module **18**, but can also be a separate, exchangeable component within the scope of the present invention. Preferably, the LED module **18** comprises pre-installed thermal gaskets or pads **30**, so that the end user does not have to apply any thermal paste (which is a tedious, delicate process) when exchanging or replacing the LED module. When installed, the LED module **18** is thermally in contact with heatsink housing **22**, which is a high-efficiency finned, thermal radiator, so that heat is dispersed from the module via the heatsink. The LED module **18** is mounted on and removed from the heatsink housing **22** via securing screws **48** (FIG. **2**) or other suitable fasteners known in the art, which can, for example, be threadedly received in bores **50** (FIG. **9**). The LED module **18** is operably connected electrically through preferably one (preferably keyed) power supply connector (or single connection plug) **52** (FIG. **8**) that is attached to interface plate **32** via screws **54** (FIG. **8**). In another embodiment, a T-slot connection can be used for operably connecting LED modules.

Heatsink or Heatsink Housing

HILL assembly **10** can comprise a heatsink that also functions as a heatsink housing **22** (FIGS. **2**, **9** and **10**) that is an open-die, finned metal extrusion formed preferably of an aluminum alloy. It will be recognized by the skilled artisan that other designs known in the art can be used, including but not limited to die castings and split extrusions. The open-die finned extrusion design is preferably used, as it offers a good combination of low price and high performance. Prior art luminaires typically have heatsink bodies that comprise two halves that are bolted or bonded together to form the heatsink. By contrast, the open-die heatsink is one piece, which has numerous benefits (i.e. low cost of assembly, sealing potential, etc.).

Thermal extrusion of the heatsink housing **22** can be used for efficient thermal management. The finned design generates a large surface area over a small length, effectively pulling heat away from the LED components. Additionally, the open cavity **56** of the heatsink housing serves as the housing for internal components, comprising at least one power supply **24**. In various embodiments, the open cavity **56** can house a plurality of power supplies.

Heatsink housing **22** comprises a groove **23** (FIG. **9**) surrounding the openings of cavity **56** at each end of the housing. An O-ring **34**, **36** (e.g., an elastomeric O-ring) is disposed in each groove **23** for sealing cavity **56** by engaging interface plate **32** and back plate **38**, respectively (FIG. **2**).

Heatsink housing **22** can also comprise fins **62** (FIGS. **2**, **9** and **10**). In certain embodiments, the fins **62** are capable of multi-angle positioning. In another embodiment, the fins can be longitudinal. In other embodiments, the fins can be arranged transversely or radially.

In certain embodiments, the heatsink housing is waterproof and/or submersible.

In another embodiment, the mounting bracket **60** is capable of multi-angle positioning.

Components for Positioning and Reducing Off-Angle Glare

Prior art luminaires reduce off-angle glare through the addition of a spun metal or refractive plastic shield, which is an additional cost. These shields are relatively large and totally block off-angle glare but do not block the dispersion of the light source, thus wasting off-angle light output of the device.

The secondary lens **12** of the first embodiment of the HILL assembly **10** can comprise a frosted lip **19** (FIG. **4**) that can be integral to the secondary lens element **12** that serves to partially attenuate the light source as seen from an angle. The cost of integrating this frosted lip **19** into the secondary lens is negligible and can be done, for example, as part of the injection molding process for forming lens element **12**.

In another embodiment, the HILL assembly can comprise a mounting bracket **60** (FIG. **2**) or any other mounting system known in the art for mounting or securing a luminaire or other lighting element. Other suitable mounting brackets for luminaires are well known in the art. In specific embodiments, the mounting bracket or system can swivel, pivot or provide multi-positioning of the HILL assembly.

As a single fixture, HILL assembly **10** supports free hanging, ceiling, wall, stanchion, and pendant mounting and can optionally comprise a sensor for sensing an environmental parameter of interest, such as an ambient light sensor **64** and/or an occupancy sensor **66** (FIG. **11**). Such sensors are well known in the art and commercially available. As will be apparent to the skilled practitioner, such optional components can be installed in a number of suitable configurations for sensing an environmental parameter of interest.

For example, in one embodiment, the ambient light sensor **64** has the ability to generate a user-defined light output profile, as described further below, based on user defined schedules or personnel detection and ambient light measuring. Light output is adjusted based on currently available light, to save the user energy by not duplicating light.

In another embodiment, the occupancy sensor **66** turns the light on/off based on user-defined time intervals.

Because HILL assembly **10** has a brick-like design that supports multi-module ganging or stacking, a single HILL assembly **10** can be ganged with other like fixtures to make, e.g., a spot light **68** (FIG. **12**), arena/stadium light **70** (FIG. **14**), or a linear fixture for wider angle lighting **72** (FIG. **13**). By employing a modular design for HILL assembly **10** and using industry standard open interfaces, the design is flexible and upgradeable.

Because HILL assembly **10** has instant on/off capabilities, it can be used in power management schemes to generate user-defined light output profiles based on user-defined schedules or personnel detection and ambient light measuring. HILL assembly **10** can be used to generate light output based on detection of currently available light (e.g., with optional ambient light sensor **66**) and to save the user energy by not duplicating light. In addition, in embodiments in which an occupancy sensor installed, HILL assembly **10** can detect, and be used in, power management schemes that switch the light on or off based on user-defined time intervals.

In one embodiment, HILL assembly **10** can predict or indicate how much time is left on the light until the lumen output decays below the L70 level (70% of lumen output at time=0 hours).

In another embodiment, HILL assembly **10** can comprise a programmable timer or timing function. Such programmable timers or timing functions are well known in the art.

Table 1 presents ranges of dimensions for various elements of HILL assembly **10**, as well as the dimensions of one preferred embodiment. It will be apparent to the skilled artisan that other suitable dimensions can be easily determined for the components of the HILL listed below, as well as for other components described herein.

TABLE 1

	Length (in)			Width (in)			Height (in)		
Part	Preferred	Max	Min	Preferred	Max	Min	Preferred	Max	Min
Secondary Lens 12	7	24	0.5	7	24	0.5	0.88	6	0.1
LED Array 20	6.15	24	0.25	6.15	48	0.25	0.06	0.25	0.01
LED Module 16	7	24	0.25	7	48	0.25	0.95	6	0.1
Heatsink 22	7	14	0.5	7	14	0.5	11	24	0.1
Mounting Bracket 60	8.17	48	0	7.45	48	0	2	6	0

A plurality of formed channels **124** receive a plurality of screws **126** that secure end cap **128** (also referred to herein as gable end cap) to heatsink **122**, as shown in FIGS. **19** and **20**. End cap **128** preferably includes at least one opening **129** (FIG. **20**) as an intake for convectional cooling air for the fins in heatsink **122**. The aspect ratio of the end cap **128** allows for a vortex to drive heat from the finned region of heatsink housing **122** and allows for driving the LEDS at higher currents than in the prior art to yield higher light output, as described in more detail below. The heatsink housing **122** can have, for example, two slits cut to increase airflow, therefore reducing the temperature of the HILL assembly.

5.2. High Intensity LED Luminaire (HILL) Assembly—Second Embodiment

A HILL assembly is also provided that is based on a modular design. In various embodiments, the HILL assembly can comprise modular lensing provided by, e.g., a lens matrix, a plurality of LED modules or modular LED arrays, joiner brackets that allow for modularity and custom angular positioning of light output, modular heatsink housing(s) and high power modular circuits (that can operate, for example, at high temperatures).

The modular lensing allows for mixing and matching of distribution patterns, which can provide precise, including but not limited to custom, optical controls.

The LED modules or modular LED arrays can have a shared cover design that allows for stacking or joining of multiple modules without the need for fasteners. An advantage of this design is that it does not interfere with the function of the heatsink. The design can allow heat to be pulled with convectional heat transfer.

The cover can also allow for modules to be attached by a joiner bracket as separate units with the cover holding them together. In a specific embodiment, a power supply can be positioned in the middle of such a modular arrangement.

Referring now to FIGS. **15-31**, a second embodiment **110** of a HILL assembly in accordance with the present invention is shown. FIGS. **15** and **16** are perspective views from above and below, respectively, of this second embodiment.

HILL assembly **110** comprises a linear, one-piece, finned, metal heatsink housing **122** formed preferably by extrusion of an aluminum alloy (see FIGS. **18-21**). Heatsink housing **122** forms the structural frame of assembly **110** and comprises several features that permit attachment of essentially all the other components of assembly **110**, as described below.

The HILL assembly can be thermally optimized for heat transfer through gable and ridge vent thermal optimization.

A plurality of mating features, e.g., T-slots **130** can receive mating features (e.g., T-mating features) **132** extending from LED module (also referred to herein as LED subassembly) **134**, as shown in FIGS. **18**, **21**, and **26**, providing secure mounting and thermal connection of LED module **134** to heatsink housing **122**. The use of T-slots increases the efficiency of the HILL assembly, and allows, for example, for mixing LED arrays together on a common track.

Opposed lips **136** receive opposed edges of a sealing lens **137**, protectively enclosing LED module **134**, and in certain embodiments, rendering it waterproof. In one embodiment, the sealing lens can be made of a transparent thermoplastic such as poly(methyl methacrylate) (PMMA).

A joiner (or "joiner bracket") **140** is also provided. Outer beaded fins **138** can receive mating edges of the joiner **140** in either a single-module HILL assembly, as shown in FIG. **26**, or optionally in a multiple-module HILL assembly. In one embodiment, this joiner is configured to allow for angular positioning to direct light output to meet specific needs.

In one embodiment, a HILL assembly module **142** can comprise a heatsink housing **122**, a LED module **134**, and a sealing lens **137**. Such a HILL assembly module **142** may be employed singly or ganged in a wide variety of configurations determined by lighting requirements and space. For example, a single module assembly can form a desk lamp or under-cabinet kitchen lamp; a double module assembly such as is shown in FIGS. **15** and **16**, can be useful as an overhead shoplight or for general overhead illumination by ceiling installation; and larger still assemblies, such as 16-module assembly **144** shown in FIG. **25**, can be useful for wide area floodlighting as in stadiums or arenas. Referring to FIG. **20**, to make the HILL assembly modular, a joiner **140** is used to fasten or connect heatsink housings together.

A bracket arm **148** is connected to either the endcap or the joiner **140** on each side of the HILL assembly. The bracket arms **148** can contain or enclose the wiring for the power

supply **150** and connect to each side of the power supply casing **146**. A bracket cover **149** can cover the bracket arm. Inside the casing **146**, at least one DC power supply **150**, and in a specific embodiment, two DC power supplies **150**, can be attached. The power supply casing permits cooling of the power supply **150**.

Referring now to FIGS. **21** through **24**, in a presently-preferred embodiment, each HILL assembly module **142** comprises two LED modules **134** disposed end-to-end (shown for clarity without sealing lens **137**). To assemble HILL assembly module **142**, the T-features **132** of each LED module are simply entered into the mating T-slots **130** in heatsink housing **122**.

The HILL assembly can have on-board "string" control and current sharing, i.e., constant on-time current control. Referring now to FIGS. **24-31***a-c*, each LED module **134** can comprise a circuit board **160** upon which are mounted 64 LEDs **162** arranged in four rows of 16 LEDs each. Preferably, the LEDs **162** in each row are wired in series and the rows **164**, also referred to herein as "strings", are wired in parallel. Circuitry **166** provides constant current to the LEDs such that if one LED fails, the circuit auto-adjusts to provide more current to the remaining LEDs, thus restoring total light output. HILL assembly module **142** includes a power supply **150** (FIG. **17**) that includes a DC-DC converter that can downstep any incoming voltage from up to 390v down to 12v operating voltage. Such a low voltage step-down converter enables high efficiency of the HILL assembly.

Circuitry **166** for driving the LEDs **162** is mounted directly on circuit board **160**, allowing the constant current feature just described, and is connected to first and second multi-prong connectors **168***a*, **168***b* at opposite ends of circuit board **160**, allowing connection to adjacent modules **134**.

Because circuitry **166** is designed specifically for these applications and is not bought off-the-shelf, circuitry **166** can be formed, in one embodiment, as an integral element of circuit board **160**. This results in greatly increased electrical efficiency of 100 lumens/watt, whereas prior art systems typically operate in the range of 80 lumens/watt. Because the light output is greater, there is less waste electrical energy and less heat generated, e.g., thermal density is reduced. This permits LEDs **162** to run continuously at only 80° C. or lower, whereas prior art systems being driven at such high light outputs must run at greater than 100° C. and are therefore prone to thermal runaway and failure.

Because circuitry **166** can operate at constant current, the power flowing to the individual LED strings **164** is balanced, preventing thermal runaway. Referring to FIG. **30**, LED driver **180** (LM3464) includes a feedback loop that continuously balances power feed to minimize temperature on each LED string **164**.

The HILL assembly can have optimized thermal transfer from the LED array to the heatsink housing through a thermally conductive material. In one embodiment, to disperse and equalize the heat generated by LEDs **162**, each LED can be positioned on the front side of circuit board **160** adjacent at least one via element (not visible) extending through circuit board **160** into connection with a via backing (not visible) on circuit board **160** formed of a thermally conductive material such as copper, beryllium oxide, aluminum, FR4, or graphene.

A secondary lens **170**, similar to secondary lens **12** in first embodiment **10**, is disposed over each LED **162**. Lenses **170** preferably are formed in modular lens matrices (also referred to herein as lens subassemblies) **172** of lenses, e.g., a 4×4 array of 16 lenses (although other suitable lens matrices can be determined by the skilled artisan) arranged in a square matrix that can be screwed down on top of its respective LEDs, as shown in FIGS. **22-24**.

To vary the size and shape of the field illuminated by each LED, the individual lenses **170** may be varied in capability, as shown in modular lens matrices (also referred to herein as lens subassemblies) **172***a* and **172***b* in FIGS. **27** and **30**, respectively. A plurality of lenses comprising at least two different types of LED lenses can be used. Preferably, LED lenses standardized by the Illumination Engineers Society of America (IESA) are employed. For example, a module **172***a*, **172***b* may comprise a plurality of Type 5 ("round") lenses **174**, a plurality of Type 3 ("butterfly") lenses **176**, and a plurality of Type 2 ("skinny") lenses **178**. It will be apparent to the skilled artisan than many different combinations of lenses can be made. Thus because of this modular matrix lensing, a HILL assembly is provided wherein different IESA standard lens types can be provided within the same light fixture.

The lenses in the modular lens matrix can be rotated or adjusted to achieve different lighting configurations with the same HILL assembly.

In one embodiment, each HILL assembly module **142** is preferably about 12 inches long and the 64 LEDs **164** are powered to emit 64,000 lumens of light. Other suitable module lengths (in the range, for example, of 6-12 inches, 12-24 inches, 24-35 inches) will be readily apparent the skilled artisan. Modules can be used to create any desired configuration of modules, e.g., 1×2, 1×3 m 1×4 m 2×2, 3×3, 3×4, 4×4 etc.

A currently preferred embodiment, as shown in FIG. **21**, provides a 24-inch heatsink housing comprising two HILL assembly modules **142**. An advantage of this design is that modular lighting can be constructed in modular sections (e.g., 12 inch sections) that can be customized in many different configurations.

Referring now to FIGS. **24**, **30***a*, **30***b*, **30***c*, **30***c*(**1**), and **31**, driver circuitry **166** allows variation of the voltage across the LED strings to a minimal value required to maintain a constant current through all four strings. This ability to vary the output voltage to a minimal value decreases the power loss of those strings that require less voltage across the LEDs. This arrangement also allows the flexibility to change the number of LEDs per string as well as the number of LED strings (1 to 4) without the need to purchase a new constant current supply as in prior art arrangement. In the present invention, this function uses a single constant voltage power supply.

In typical prior art applications, a constant current supply is utilized without the use of circuitry to vary the output voltage, meaning that the constant current power supply's output voltage just climbs to whatever voltage the highest LED string needs. The other strings that require less voltage need to dissipate the excess power created by the high voltage setting which leads to inefficient and less reliable designs. In the prior art, if the number of LEDs were to change, a new version of constant current power supply would need to be selected.

In certain embodiments, the LEDs **162** can be dimmable by pulse width modulation (PWM). Thus, the HILL assembly can also comprise pulse width modulation (PWM) circuitry. The PWM circuitry converts the 0-10V analog signal to a PWM signal.

A method for maintaining a constant LED color temperature (CCT) and/or a color rendering index (CRI) in a lighting assembly (e.g., a HILL assembly) is also provided. The method comprises the steps of using constant drive current,

thereby decreasing photon emissions; and varying pulse width modulation (PWM). These steps together provide overall dimming of the light output at frequencies higher than are currently on the market. Constant CCT and CRI are maintained while dimming from 100% to 0% because of this pulse width modulation (PWM).

With PWM come the benefits of maintaining a constant LED color temperature (CCT) and color rendering index (CRI). Preferably, PWM is conducted at higher frequencies in the range of 10 kHz to 20 kHz to comply with high definition cameras/filming. The higher frequency range also allows elimination of any audible noise in applications where necessary to do so.

In a specific embodiment, pulse width modulation (PWM) can be used at a frequency of 10 GHz to 24 GHz as a method to dim the light output. This frequency range allows the light output to be dimmed at an optimal frequency that is ideal for not interfering with other visible activities, including, but not limited to high definition television recording and broadcasting. Using PWM to dim the light output maintains the Color Rendering Index (CRI) and Color Temperature (CCT) of the LED.

In certain embodiments, the HILL comprises a 0-10V dimmer circuit. This allows the advantage of using a commercially available 0-10V dimmer switch, but such a switch does not provide a pulse width modulation (PWM) output.

In one embodiment, the HILL assembly is preferably IEC6929 annex compliant (on board) for 0-10V operation.

In a preferred embodiment, a HILL assembly comprises both a 0-10V dimmer circuit and a pulse width modulation (PWM) circuit. Positioning the circuitry adjacent to, or in association with the LEDs is particularly preferred. 2) there is constant voltage 3) pulse width modulation.

5.3. Methods for Making HILL Assemblies

The HILL assemblies disclosed herein can be made using conventional manufacturing techniques known in the art. The construction of the elements of the HILL assemblies will be readily apparent to the skilled practitioner. For example, heatsinks can be produced by conventional extrusion techniques. Power supplies and circuit boards are also made using conventional methods. No special manufacturing techniques or manufacturing environments are needed to produce the assemblies.

5.4. Index for Numbered Elements

10 HILL assembly, first embodiment
12 lens (or secondary lens) element
14 CCLs
16 LED module
18 LEDs
19 frosted lip
20 first LED array
22 heatsink housing
23 groove surrounding the openings of cavity **56**
24 power supply
25 concave lens surface of each CCL **14**
26 convex lens surface
28 first O-ring
30 first and second thermal gaskets
32 interface plate
34 second O-ring for sealing heatsink housing **22** at the front end
36 third O-ring for sealing heatsink housing **22** at the rear end back plate
38 back plate
40 junction box
42 sealing gaskets
44 securing screws
46 circuit board or card
48 securing screws
50 bores
52 power supply connector
54 screws
56 open cavity
60 mounting bracket
62 fins of heatsink housing **22**
64 ambient light sensor
66 occupancy sensor
68 spot light
70 arena/stadium light
72 linear fixture for wider angle lighting
110 HILL assembly, second embodiment
122 linear, one-piece, finned, metal heatsink housing
124 channels
126 screws
128 end plate
129 opening in end plate
130 T-slots
132 mating T-features
134 LED module
136 opposed lips
137 sealing lens
138 outer beaded fins
140 joiner **140**
142 HILL assembly module
144 16-module assembly
146 power supply casing
148 bracket arm
149 bracket cover
150 power supply
151 electrical access cover
152 power supply wires
154 openings to allow venting of heated air from the fins
156 bottom panel
160 circuit board
162 LEDs
166 driver circuitry for driving the LEDs
168*a*, **168*b*** first and second multi-prong connectors
170 secondary lens
172, **172*a*** and **172*b*** lens matrix
174 round lenses
176 butterfly lenses
178 skinny lenses
180 LED driver

The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

While embodiments of the present disclosure have been particularly shown and described with reference to certain examples and features, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the present disclosure as defined by claims that can be supported by the written description and drawings. Further, where exemplary embodiments are described with reference to a certain number of elements it will be understood that the exemplary embodiments can be practiced utilizing either less than or more than the certain number of elements.

All references cited herein are incorporated herein by reference in their entirety and for all purposes to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety for all purposes.

The citation of any publication is for its disclosure prior to the filing date and should not be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention.

What is claimed is:

1. A light emitting diode (LED) luminaire assembly, comprising:

a LED module comprising an array of a plurality of LEDs;

a circuit board;

a secondary lens structure comprising an array of lenses, wherein the lenses comprise concavo-convex lenses such that each lens creates wide dispersion optics, and wherein the lenses are positioned so that each LED is positioned entirely within a concave surface of a corresponding lens element lens;

a heatsink; and

driver circuitry for driving the LEDs in communication with the circuit board.

2. The LED luminaire assembly of claim **1**, wherein:

the heatsink comprises a housing that includes a plurality of channels and a plurality of mating features for that mount and provide a thermal connection of the LED module to the housing; and

the assembly further comprises:

a sealing lens that protectively encloses the LED module within the housing, and

a mounting bracket capable of multi-angle positioning of the housing.

3. The LED luminaire assembly of claim **1**, wherein:

the plurality of lenses in the secondary lens structure are formed in a plurality of modular lens matrices, and at least two of the matrices comprise different lenses.

4. The LED luminaire assembly of claim **1**, wherein the LED assembly comprises one or more gaskets and is removable from the heatsink.

5. The LED luminaire assembly of claim **1**, wherein the lenses of the secondary lens structure are integrated into a singular lens element and are comprised of plastic, acrylic, glass or polycarbonate.

6. The LED luminaire assembly of claim **1**, wherein:

the LED array comprises a plurality of parallel strings of LEDs; and

the driver circuitry is configured to provide a constant current to the LED so that voltage delivered to each string of LEDs is automatically adjusted if any LED in the string fails.

7. The LED luminaire assembly of claim **1**, wherein the driver circuitry further comprises pulse width modulation circuitry configured to enable dimming of the LEDs by varying pulse width modulation.

8. The LED luminaire assembly of claim **1**, wherein the driver circuitry further comprises feedback circuitry for balancing power input to each of a plurality of LED strings.

9. The LED luminaire assembly of claim **1**:

wherein a housing of the heatsink comprises a plurality of fins; and

the assembly further comprises an end cap that is secured to the heatsink and which includes at least one opening that is an intake for convectional cooling air into the heatsink which drives heat away from the fins of the heatsink housing.

10. The LED luminaire assembly of claim **1**, further comprising a sensor for sensing or providing data relating to the LED luminaire assembly or to environmental parameters.

11. The LED luminaire assembly of claim **1**, further comprising:

a power supply; and

a bracket body comprising at least one arm configured to support the assembly wherein the bracket body provides a cavity that holds the power supply.

12. The LED luminaire assembly of claim **1**, wherein the secondary lens structure further comprises a hexagonal lens configured to create a uniform distribution of light from the plurality of LEDs.

13. The LED luminaire assembly of claim **2**, wherein the sealing lens comprises a frosted lip for attenuating light emitted by the assembly.

14. A method of operating a LED luminaire assembly comprising a LED module comprising a plurality of LED strings each comprising a plurality of LEDs, a circuit board, a secondary lens structure comprising an array of lenses, a heatsink, and driver circuitry, the method comprising:

driving the plurality of LED strings at a constant current and varying pulse width modulation;

wherein the lenses elements of the secondary lens structure comprise concavo-convex lenses such that each lens creates wide dispersion optics, and wherein the lens elements are positioned so that each LED is positioned entirely within a concave surface of a corresponding lens.

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